Poznan University of Physical Education

TRENDS in SPORT SCIENCES

(formerly Studies in Physical Culture and Tourism)

quarterly • number 1 • volume 30 • year 2023

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ISSN 2299-9590

Publisher
Poznan University of Physical Education
ul. Królowej Jadwigi 27/39
61-871 Poznań, Poland
tel. +48 61 835 51 96
e-mail: gronek@awf.poznan.pl
e-mail: tss@awf.poznan.pl
www.tss.awf.poznan.pl

Printed by
ESUS Tomasz Przybylak
ul. Południowa 54
62-064 Plewiska, Poland

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ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**1**): 5-11
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.1-1

Match performance difference between African and Top Five teams in the group stage of the 2022 World Cup

OUSSAMA KESSOURI

Abstract
Introduction. The analysis of technical performance in soccer helps to identify the most important variables that distinguish successful teams from their unsuccessful counterparts. Aim of Study. This study aimed to determine the difference in the match performance between the African national teams and the Top Five teams in the group stage of the 2022 World Cup. Material and Methods. Data were collected from the Whoscored website for five African national teams (Morocco, Senegal, Ghana, Cameron, and Tunisia) and five successful teams in the tournament (Argentina, France, Croatia, Brazil, and England). Independent t-test was used to compare match statistics between the African teams and the Top Five teams, while the effect size (ES) was used to find determine the magnitude of differences between the groups in those statistics. Results. The results showed that the Top Five teams outperformed the African teams in total shots ($p < 0.05$; ES = 1.47), shots on target ($p < 0.01$; ES = 2.68), and shooting from open play ($p < 0.05$; ES = 1.46), possession ($p < 0.001$; ES = 3.95), total passes ($p < 0.001$; ES = 5.90), passing accuracy ($p < 0.001$; ES = 5.35), short passes ($p < 0.001$; ES = 6.17), long ball accuracy ($p < 0.05$; ES = 2.08), and key passes ($p < 0.05$; ES = 1.53). In contrast, the African teams played more long balls (54.20 ± 6.61 vs 44.00 ± 8.71; ES = –1.31), committed many fouls ($p < 0.05$; ES = –1.84), made more clearances ($p < 0.001$; ES = –4.30) and saves by goalkeepers ($p < 0.05$; ES = –2.02), and received more yellow cards ($p < 0.01$; ES = –2.21) than their Top Five counterparts. Conclusions. In conclusion, the technical performance of the Top Five teams during the 2022 World Cup was better than the performance of the African teams, especially concerning passing and shooting variables. Therefore, this study can give African coaches an indication of the technical requirements for success in the upcoming World Cup.

KEYWORDS: key performance indicators, possession play, goal scoring, international soccer, African football, World Cup.

Received: 1 February 2023
Accepted: 6 March 2023

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Introduction

Soccer is the most popular sport in the world with about 270 million participants worldwide. It is a sport that is organized and developed by the Fédération Internationale de Football Association (FIFA), which was founded in 1904. The World Cup is an international tournament organized by FIFA every four years since its first edition in 1934, in which 32 national teams from six continental zones participate after passing the qualifying rounds [27]. In the World Cup, 13 teams from the Union of European Football Associations (UEFA), 5 teams from the Confederation of African Football (CAF), and 4 or 5 from the Asian Football Confederation (AFC) participate, with 4 or 5 teams from the South American Football Confederation (CONMEBOL), 3 or 4 teams from the Confederation of North, Central America and Caribbean Association Football (CONCACAF), and 0 or 1 from the Oceania Football Confederation (OFC), in addition to the Hosts [7]. These teams are divided into 8 groups with 4 teams in each group. After playing 3 matches for each team, the first and second of each group qualify for the knockout stages, which are represented in the round of 16, the quarter-finals, the semi-finals, the ranking match (third-place), and then the final [27].

In every edition of the World Cup, 5 African national teams out of 54 teams participate after passing the qualifying stage. Most of these teams have many good players in their squads who play in major European leagues (English Premier League, La Liga, Bundesliga, Serie A, and French Ligue 1), in addition to local players [1]. Despite this fact, no African national team has ever won the World Cup [26], and their best achievements is the Cameroon national team reaching the quarter-finals of the 1990 World Cup, Senegal in 2002, and Ghana in the 2010 edition in South Africa [1]. Perhaps the most prominent achievement is the Moroccan national team reaching the semi-finals of the World Cup 2022 to become the most successful African side in World Cup history.

On the other hand, 13 European national teams are participating in the tournament out of 55 teams, while 4 or 5 teams from South America are participating out of 34 teams. These teams have dominated the tournament since the first in Uruguay in 1930. The European teams won 12 titles, while the South American teams won 10 titles. This dominance may be due to several geographical, cultural, and economic factors. As Jamil [12] proved that players differ in terms of physical abilities and technical skills from one country to another, and he concluded that European and South American players perform better movements related to passing and shooting than African players. This may confirm the difference in the playing styles that the coaches follow in proportion to the abilities and characteristics of their players [16]. In the five major leagues in Europe, the playing style varies between fast and direct play, possession, and counter-attacks, depending on the physical fitness and morphological of the players such as the English Premier League, or depending on the technical quality of the players, such as the Spanish League (La Liga) [24]. It should be noted here that many studies in recent years have proven that variables related to possession of the ball, passing, and successful shooting are the main factors for success in soccer [13].

Playing styles can evolve and change [12], and the evolving of the idea of soccer in Germany more towards the technical development of the players is an example of that trend [9]. This development requires good quality training and huge training facilities and equipment. This leads us to the economic factor, since sport represents in European countries a good percentage of the countries' gross domestic product (GDP). These countries work to develop soccer and various social and economic activities related to it, unlike African countries that lack professionalism and the availability of facilities and equipment that help the player reach his best potential [2].

Match-related technical performance is among good indicators that may explain the success or failure of teams in the World Cup tournament. Many studies have analyzed the match performance of successful and unsuccessful teams in this tournament. It has been shown that the winning teams in 2002, 2006, and 2010 World Cups had more shots on target and possession of the ball than the losing or drawing teams [5]. In recent editions, Liu et al. [21] showed that successful teams in the 2014 World Cup had a greater number of shots, shots on target, shots from counterattacks, shots from inside the penalty area, ball possession, short passes, average pass streak, aerial advantage, and tackles than unsuccessful teams. Kubayi and Larkin [14] also showed that the teams that qualified from the group stage to the knockout stage in the 2018 World Cup made a great number of shots on target, total passes, accurate passes, medium passes, and ball possession than eliminated teams.

Analyzing technical performance by collecting match statistics and comparing teams can help determine the success factors of the European and South American national teams in the World Cup, as well as help to know the level of performance of African teams that did not win the tournament compared to the most successful teams in the last World Cup in 2022. For this purpose the main aim of this study was to determine differences in match technical performance between the Top Five and African national teams in the group stage of 2022 World Cup.

Material and Methods

Sample

Because the number of matches between African teams and the Top Five teams in the world is not equal, given the advanced stages reached by the Top Five, the study sample included soccer matches for African national teams and the Top Five teams in the group stage of the FIFA World Cup 2022 in Qatar, where the number of matches was 15 for African teams, and 15 matches for the Top Five teams. The number of African teams was 5 teams (n = 5), which is the number allocated to African teams by FIFA to participate in the World Cup, and these teams were represented by Morocco, Senegal, Cameroon, Tunisia, and Ghana. For the Top Five teams (n = 5), they were chosen according to the stage they reached in the tournament (World Cup 2022), and they were represented by the teams that reached the semi--finals and the final, which are Argentina, France, and Croatia, while the other 2 teams were chosen as they reached the quarter-finals in addition to the previous teams. These teams were Netherlands, Brazil, Portugal, and England, and given the FIFA classification of international teams, Brazil and England were chosen to complete the number of the Top Five teams (Argentina, France, Croatia, Brazil, and England).

Data and reliability

Match statistics for previous teams were collected from the international Whoscored website (www.whoscored.com), which is specialized in providing accurate statistics for players and teams that play in international leagues and tournaments through its use of the Opta system. Data were collected from this site, especially after Liu et al. [22] demonstrated that the Opta system is a reliable tracking system to collect match statistics (intra-class correlation coefficients: 0.88-1.00; standardized typical error: 0.00-0.37). It was used in several previous studies on the analysis of soccer matches in La Liga [20], the UEFA Champions League [29], and the FIFA World Cup [14, 21]. The current study followed the Helsinki declaration [28].

Match performance variables

Twenty-five variables expressing the technical performance of soccer matches were selected. These indicators were distributed into 3 groups represented by 7 variables related to attacking and scoring, 10 variables related to passing and organizing, and 8 variables related to defending. These variables were selected through previous studies [19, 20, 21, 29] with the addition or deletion of some variables that serve or do not serve the current study. Table 1 shows the various variables chosen in this study.

Table 1. Match performance indicators included in the study

Groups	Variables
Attacking and goal scoring	total shots; shots on target; shots from open play; shots from counter attack; goal efficiency (goals × 100/total shots); dispossessed and offside
Passing and organizing	possession (%); total passes; pass accuracy (%); short passes; long balls; long balls accuracy (%); crosses; through balls; key passes and successful dribbles
Defending	tackles; interceptions; fouls; clearances; shots blocked; total saves; yellow card, and red card

Statistical analysis

After collecting data from the Whoscored website, statistics were arranged in Microsoft Excel 2021 (Excel 2021, Microsoft, Washington, USA), and then transferred to SPSS v26 (SPSS 26, IBM, Armonk, USA) for statistical analysis. All data were expressed as mean ± standard deviation (SD). Student's t-test was used for two independent samples to compare match statistics between African teams and the Top Five teams. The significance level was considered to be $p \leq 0.05$. For more accurate results, the effect size (ES) was used to find out the magnitude of differences between groups in all variables. ES values were estimated as described by Hopkins et al. [10], based on the smallest worthwhile change (SWC) and the standardized difference in ES (90% CI), as trivial (<0.20), small (0.20-0.59), moderate (0.60-1.19), large (1.20-2.00), and very large (>2.00).

Results

Table 2 shows the difference between the match technical performance between the African teams and the Top Five teams during the group stage of the FIFA World Cup Qatar 2022.

Regarding the variables related to attacking and goal scoring, significant differences were obtained in total shots ($p < 0.05$; ES = 1.47), shots on target ($p < 0.01$; ES = 2.68), and shooting from open play ($p < 0.05$; ES = 1.46) in favor of the Top Five teams. The results also revealed that there were no significant differences in shooting from counterattack ($p > 0.05$; ES = 0.39), goal efficiency ($p > 0.05$; ES = 0.00), dispossessed ($p > 0.05$; ES = –0.44), and offside ($p > 0.05$; ES = 0.18). For the variables related to passing and organizing, there are significant differences in possession ($p < 0.001$; ES = 3.95), total passes ($p < 0.001$; ES = 5.90), passing accuracy ($p < 0.001$; ES = 5.35), short passes ($p < 0.001$; ES = 6.17), long ball accuracy ($p < 0.05$; ES = 2.08), and key passes ($p < 0.05$; ES = 1.53) in favor of the Top Five teams, while there were no significant differences in long balls ($p > 0.05$; ES = –1.31), crosses ($p > 0.05$; ES = 0.83), through balls ($p > 0.05$; ES = 0.95), and successful dribbles ($p > 0.05$; ES = –0.17).

Finally, significant differences were obtained in some defense-related variables, represented in fouls ($p < 0.05$; ES = –1.84), clearances ($p < 0.001$; ES = –4.30), total saves ($p < 0.05$; ES = –2.02), and yellow card ($p < 0.01$, ES = –2.21) in favor of African teams. As for the other variables, there were no significant differences between the African teams and the Top Five teams, and these variables are the number of tackles ($p > 0.05$; ES = –0.01), interceptions ($p > 0.05$; ES = –0.61), shots

Table 2. Differences in match performance variables between African and Top Five national teams in the 2022 FIFA World Cup

Variable	Top Five teams (mean ± SD)	African teams (mean ± SD)	Sig	ES
Variables related to attacking and goal scoring				
Total shots	14.80 ± 3.78	10.14 ± 2.37	0.048*	1.47 (large)
Shots on target	6.08 ± 0.72	3.60 ± 1.09	0.003**	2.68 (very large)
Shots from open play	10.06 ± 2.31	7.07 ± 1.72	0.046*	1.46 (large)
Shots from counterattack	0.52 ± 0.67	0.32 ± 0.24	0.550	0.39 (small)
Goal efficiency	12.94 ± 6.44	12.94 ± 6.30	0.999	0.00 (trivial)
Dispossessed	9.24 ± 1.92	10.52 ± 3.58	0.502	–0.44 (small)
Offside	2.06 ± 1.30	1.86 ± 0.82	0.780	0.18 (trivial)
Variables related to passing and organizing				
Possession (%)	61.04 ± 5.52	42.16 ± 3.90	0.000***	3.95 (very large)
Total passes	604.72 ± 51.89	377.22 ± 16.66	0.000***	5.90 (very large)
Pass accuracy (%)	87.30 ± 1.36	79.08 ± 1.69	0.000***	5.35 (very large)
Short passes	565.40 ± 52.76	327.40 ± 13.63	0.000***	6.17 (very large)
Long balls	44.00 ± 8.71	54.20 ± 6.61	0.071	–1.31 (large)
Long balls accuracy (%)	55.02 ± 6.96	43.05 ± 4.21	0.011*	2.08 (large)
Crosses	19.80 ± 2.86	16.40 ± 5.02	0.225	0.83 (large)
Through balls	1.60 ± 0.54	1.00 ± 0.70	0.172	0.95 (large)
Key passes	11.14 ± 3.20	7.20 ± 1.70	0.041*	1.53 (large)
Successful dribbles	7.14 ± 1.57	7.40 ± 1.35	0.787	–0.17 (trivial)
Variables related to defending				
Tackles	17.14 ± 6.00	17.20 ± 4.82	0.987	–0.01 (trivial)
Interceptions	7.88 ± 2.50	9.50 ± 2.77	0.361	–0.61 (moderate)
Fouls	9.21 ± 2.41	13.20 ± 1.89	0.018*	–1.84 (large)
Clearances	12.74 ± 2.68	24.66 ± 2.86	0.000***	–4.30 (very large)
Shots blocked	2.74 ± 1.23	2.68 ± 1.23	0.941	0.04 (trivial)
Total saves	1.00 ± 0.62	2.66 ± 0.98	0.013*	–2.02 (very large)
Yellow card	0.54 ± 0.39	1.82 ± 0.72	0.008**	–2.21 (very large)
Red card	0.00 ± 0.00	0.06 ± 0.13	0.347	–0.65 (moderate)

Note: SD – standard deviation, Sig – significant, ES – effect size
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

blocked ($p > 0.05$; ES = 0.04), and red card ($p > 0.05$; ES = –0.65).

Discussion

The purpose of this study was to determine the difference in the match technical performance in the group stage of the World Cup 2022 between the African and the Top Five national teams. The main findings of the current study indicated that there were statistically significant differences in favor of the Top Five teams in some variables related to attack and goal scoring represented in total shots, number of shots on target, and shots from open play, as well as in some variables related to passing and organizing (possession of the ball, total passes, number of short passes, passing accuracy, long ball accuracy, and number of key passes), while statistically significant differences were found in favor of African teams in some defense-related variables represented in fouls, clearances, total saves, and yellow cards.

Variables related to attacking and goal scoring

Regarding these variables, significant differences were obtained in total shots ($p < 0.05$; ES = 1.47), shots on target ($p < 0.01$; ES = 2.68), and shooting from open play ($p < 0.05$; ES = 1.46). This means that the Top Five teams performed more offensively than the African teams and created more chances to score goals, which is similar to previous findings. Kubayi and Toriola [15] found that European teams had more shots and more shots on target than the African teams during the 2018 World Cup. These results are also consistent with the findings of many previous studies, where the successful teams outperformed the unsuccessful teams in the number of shots and shots on target in various tournaments and leagues, which are represented in the FIFA World Cup [5, 14, 21], the UEFA Champions League [6, 18, 23], La Liga [20]. Thus, the results of this study are added to the studies that consider that creating many opportunities for shooting and shots on target is one of the most important factors for success in football matches.

While results related to shots from counterattacks indicate that both the African and the Top Five teams performed similarly, this differed from what Lepschy et al. [19] found. Thus, shooting from counterattack was a success factor for teams participating in World Cup 2014 and 2018.

For another attacking and goal scoring variable, which was previously shown by Yue et al. [30] that goal efficiency (quality of shot) is more important than the number of shots in Bundesliga matches, the current study showed that both African and the Top Five teams are similar in goal efficiency (12.94 ± 6.44 vs 12.94 ± 6.30).

As for the offside and dispossessed variables, there is no difference between the African and the Top Five teams in these variables. These results are consistent with previous findings [14] and differed from what Jamil found, as the African players recorded more offside and dispossessed than European players [12].

Variables related to passing and organizing

The results associated with these variables showed that there were significant differences in possession of the ball ($p < 0.001$; ES = 3.95), total passes ($p < 0.001$; ES = 5.90), passing accuracy ($p < 0.001$; ES = 5.35), short passes ($p < 0.001$; ES = 6.17), long ball accuracy ($p < 0.05$; ES = 2.08), and key passes ($p < 0.05$; ES = 1.53) in favor of the Top Five national teams. This is similar to what was previously found, as European teams outperformed African teams in these variables in the 2018 World Cup [14]. Jamil [12] found through a study of the most skilled players in the world that European and South American players are more efficient at passing actions than African players. This is confirmed by this study, as the percentage of successful passes for African teams is significantly lower compared to the Top Five teams.

Generally, these variables were one of the most important factors for successful teams in the FIFA World Cup [14, 21], UEFA Champions League [29], and Spanish Professional Soccer League [17].

It was previously reported maintaining the ball for a long time and playing many successful passes helps teams organize the attack, enter to the final third and creates many scoring opportunities [3, 8, 11, 21]. This is evident in the current study, where the Top Five teams created more scoring opportunities than their African counterparts. In contrast, the African teams had more long balls than the Top Five teams (54.20 ± 6.61 vs 44.00 ± 8.71; ES = –1.31), and this is what makes them lose possession [25]. These results are similar to previous findings, where African teams play more long balls than European teams [15]. Kubayi and Larkin [14] also found that eliminated teams in the group stage of the 2022 World Cup had more long balls compared to teams that qualified for the knockout stages.

Regarding the number of crosses and through balls, this study indicates that the Top Five teams did more crosses and through balls than African teams (19.80 ± ± 2.86 vs 16.40 ± 5.02; ES = 0.83; and 1.60 ± 0.54 vs 1.00 ± 0.70; ES = 0.95; respectively), which is inconsistent with previous findings in the FIFA World Cup 2014 and 2018, where crosses had a significant negative effect for winning the matches [19].

It was previously reported that successful dribbles were not an important factor in the success of the teams [14, 20], and this was confirmed by the current study, where successful dribbling was similar for both African and the Top Five teams.

Variables related to defending

Results show that the African teams made more fouls ($p < 0.05$; ES = –1.84), clearances ($p < 0.001$; ES = –4.30), total saves ($p < 0.05$; ES = –2.02), and received more yellow cards ($p < 0.01$; ES = –2.21) than the Top Five teams. However, there are no significant differences in tackles, interceptions, shots blocked, and red cards. These findings are consistent with previous literature, as Kubayi and Toriola [15] showed that African teams made more fouls and received more yellow card than European teams in the 2018 World Cup.

Generally, unsuccessful teams often commit more fouls and make more clearances and receive more yellow cards than successful teams [14, 29]. This may affect the performance of the players, as receiving yellow cards leads to a decrease in the players' defensive level due to their fear of receiving a second yellow card [21].

For variables of clearances and total saves, Lepschy et al. [19] found that clearance is a key factor to success in the 2014 and 2018 World Cups. Andrzejewski et al. [3] showed that goalkeeper saves also are important to success in the German Bundesliga. However these variables also reflect the reception of many opportunities to score goals.

Limitations and future research

In this study, several technical performance indicators were studied, but not all variables were addressed. In addition, only one factor of the various factors on which a soccer match depends was investigated. While soccer does not depend on the technical aspect only, its performance is controlled by several other factors represented in the physical, tactical, psychological, and external factors such as humidity, altitude, and field condition [4]; therefore, this study may be a starting point for other studies to look in depth on the multiple causes that lead to the failure of African national teams to win the World Cup.

Also, in the current study, data were collected from the group stage only and one World Cup (2022 edition). Therefore, future studies can collect data for the last four or five editions of the World Cup for African teams and the five best teams in each edition. This is what many studies have done in terms of the difference between successful and unsuccessful teams in the World Cup. Castellano et al. [5] collected data from the 2002, 2006, and 2010 World Cup editions, while Lepschy et al. [19] studied the success factors of the teams for two editions, 2014 and 2018.

Conclusion

The results of the current study indicate that the Top Five teams are superior to African teams in terms of possession of the ball, number of passes, number of short passes, passing accuracy, key passes, the accuracy of long balls, number of shots, shooting on target and shooting from open play. In contrast, the African teams played more long balls, committed a lot of fouls, made more clearances and saves by goalkeepers, and received more yellow cards than their Top Five counterparts. It is due to that fact that African teams concede more goal scoring chances, make more fouls, play more long balls (mostly inaccurately) and create fewer goal scoring chances compared to more successful teams. These results indicate that African teams should evaluate their current performance, rethink their playing style and improve their technical and tactical work. Therefore, if the African teams perform similarly to the performance of the Top Five teams, they could have great chances to pass the group stage and reach the final rounds of the upcoming World Cup.

Conflict of Interest

The author declares no conflict of interest.

References

1. Acheampong EY, Akwaa-Sekyi EK, Bouhaouala M. How does team composition affect performance in continental tournaments?. Cogent Soc Sci. 2019;5(1). https://doi.org/10.1080/23311886.2019.1606133
2. Acheampong EY, Bouhaouala M, Raspaud M. Socioeconomic analysis of African footballers' migration to Europe. In: Onwumechili C, editor. Africa's Elite Football Structure, Politics, and Everyday Challenges. London: Routledge; 2019. pp. 58-73. https://doi.org/10.4324/9780429029059-5
3. Andrzejewski M, Oliva-Lozano JM, Chmura P, Chmura J, Czarniecki S, Kowalczuk E, et al. Analysis of team success based on match technical and running performance in a professional soccer league. BMC Sports Sci Med Rehabil. 2022;14(1):82. https://doi.org/10.1186/s13102-022-00473-7
4. Bangsbo J, Mohr M, Poulsen A, Perez-Gomez J, Krustrup P. Training and testing the elite athlete. J Exerc Sci Fit. 2006;4(1):1-14.
5. Castellano J, Casamichana D, Lago C. The use of match statistics that discriminate between successful and unsuccessful soccer teams. J Hum Kinet. 2012;31:139--147. https://doi.org/10.2478/v10078-012-0015-7
6. Collet C. The possession game? A comparative analysis of ball retention and team success in European and international football, 2007-2010. J Sports Sci. 2013;31(2):123-136. https://doi.org/10.1080/02640414.2012.727455
7. FIFA. FIFA World Cup Qatar 2022 regulations. Zurich: Fédération Internationale de Football Association; Aug 11, 2022. Retrieved Jan 4, 2023, from: https://digitalhub.fifa.com/m/2744a0a5e3ded185/original/FIFA-World-Cup-Qatar-2022-Regulations_EN.pdf.

8. Grant A, Williams AM, Lee D, Reilly T. Analysis of the successful and unsuccessful teams in the 1998 World Cup. Insight FA Coaches Assoc J. 1998;1:21-24.
9. Grossmann B, Lames M. From talent to professional football – youthism in German football. Int J Sports Sci Coach. 2015;10(6):1103-1113. https://doi.org/10.1260/1747-9541.10.6.1103
10. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009;41(1):3-13. https://doi.org/10.1249/MSS.0b013e31818cb278
11. Hughes M, Franks I. Analysis of passing sequences, shots and goals in soccer. J Sports Sci. 2005;23(5):509--514. https://doi.org/10.1080/02640410410001716779
12. Jamil M. Where do the best technical football players in the world come from? Analysing the association between technical proficiency and geographical origin in elite football. J Hum Sport Exerc. 2022;17(2):244-260. https://doi.org/10.14198/jhse.2022.172.02
13. Jamil M, McErlain-Naylor SA, Beato M. Investigating the impact of the mid-season winter break on technical performance levels across European football – does a break in play affect team momentum? Int J Perform Anal Sport. 2020;20(3):406-419. https://doi.org/10.1080/24748668.2020.1753980
14. Kubayi A, Larkin P. Match performance variables that differentiated between qualified and eliminated teams in the group stages of the 2018 FIFA World Cup. Ger J Exerc Sport Res. 2022;52:105-109. https://doi.org/10.1007/s12662-021-00744-4
15. Kubayi A, Toriola A. Differentiating African teams from European teams: identifying the key performance indicators in the FIFA World Cup 2018. J Hum Kinet. 2020;73(1):203-208. https://doi.org/10.2478/hukin- 2019-0144
16. Kvas-Cabral V, Martins H, Oneda G, Enes A, Moraes I, Leonel D. Physical, technical, and tactical differences between continental soccer teams participating in the 2018 FIFA World Cup. J Phys Educ Sport. 2022;22:1507--1515. https://doi.org/10.7752/jpes.2022.06190
17. Lago-Ballesteros J, Lago-Peñas C. Performance in team sports: identifying the keys to success in soccer. J Hum Kinet. 2010;25:85-91. https://doi.org/10.2478/v10078-010-0035-0
18. Lago-Peñas C, Lago-Ballesteros J, Rey E. Differences in performance indicators between winning and losing teams in the UEFA Champions League. J Hum Kinet. 2011;27:135-146. https://doi.org/10.2478/v10078-011-0011-3
19. Lepschy H, Woll A, Wäsche H. Success factors in the FIFA 2018 World Cup in Russia and FIFA 2014 World Cup in Brazil. Front Psychol. 2021;12:638690. https://doi.org/10.3389/fpsyg.2021.638690
20. Liu H, Gómez MA, Gonçalves B, Sampaio J. Technical performance and match-to-match variation in elite football teams. J Sports Sci. 2016;34(6):509-518. https://doi.org/10.1080/02640414.2015.1117121
21. Liu H, Gomez MÁ, Lago-Peñas C, Sampaio J. Match statistics related to winning in the group stage of 2014 Brazil FIFA World Cup. J Sports Sci. 2015;33(12):1205--1213. https://doi.org/10.1080/02640414.2015.1022578
22. Liu H, Hopkins W, Gómez AM, Molinuevo SJ. Inter--operator reliability of live football match statistics from OPTA Sportsdata. Int J Perform Anal Sport. 2013;13(3):803-821. https://doi.org/10.1080/24748668.2013.11868690
23. Liu H, Yi Q, Giménez JV, Ruano MG, Peñas CL. Performance profiles of football teams in the UEFA Champions League considering situational efficiency. Int J Perform Anal Sport. 2015;15:371-390.
24. Mitrotasios M, Gonzalez-Rodenas J, Armatas V, Aranda R. The creation of goal scoring opportunities in professional soccer. Tactical differences between Spanish La Liga, English Premier League, German Bundesliga and Italian Serie A. Int J Perform Anal Sport. 2019;19(3):452-465. https://doi.org/10.1080/24748668.2019.1618568
25. Reis MAM dos, Vasconcellos FV do A, Almeida MB de. Analysis of the effectiveness of long distance passes in 2014 Brazil FIFA World Cup 2017. Revista Brasileira de Cineantropometria e Desempenho Humano. 2017;19:676--685. https://doi.org/10.5007/1980-0037.2017v19n6p676
26. Simiyu WN. Africa at the Football World Cup, 1934-2018: defining moments and memories on the field. Soccer Soc. 2019;20:973-985. https://doi.org/10.1080/14660970.2019.1680497
27. Wong DP, Mujika I, Castagna C, Chamari K, Lau WCP, Wisloff U. Characteristics of World Cup soccer players. Soccer J. 2008;53(1):57-62.
28. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-2194. https://doi.org/10.1001/jama. 2013.281053
29. Yi Q, Gómez M, Liu H, Sampaio J. Variation of match statistics and football teams' match performance in the group stage of the EUFA Champions League from 2010 to 2017. Kinesiology (Zagreb). 2019;51(2):170-181. https://doi.org/10.26582/k.51.2.4
30. Yue Z, Broich H, Mester J. Statistical analysis for the soccer matches of the First Bundesliga. Int J Sports Sci Coach. 2014;9(3):553-560. https://doi.org/10.1260/1747-9541.9.3.553

ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**1**): 13-19
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.1-2

Prevalence of gymnastics-based movement ability/inability among high-intensity functional training practitioners

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Abstract

Introduction. Gymnastics-based exercises comprise complex movements used in many high-intensity functional training (HIFT) workouts, but the prevalence of ability/inability to perform these exercises is unknown. Aim of Study. This study investigated the rate of practitioners able/unable to perform each gymnastics-based movement applied in HIFT workouts. Material and Methods. Using a "virtual snowball" sampling method 1325 volunteers (women: 738; men: 587) answered an online survey. The rates for the ability/inability were estimated for the following movements: pull-up (PU) and its variations (strict pull-up [SPU], kipping/butterfly PU, strict chest-to-bar [SCtB], kipping/butterfly CtB), strict (STtB) and kipping toes-to-bar (TtB), bar muscle--up (BMU), ring muscle-up (RMU), handstand hold, handstand push-up (HSPU) and handstand walk (HSW). The rates were also stratified according to sex. Results. Our results demonstrated a high rate of inability in strict movements: SPU, SCtB, STtB, strict HSPU, strict BMU, strict RMU, and handstand hold, especially among women. The use of the kipping technique allowed one to perform many of these movements, since the prevalence of inability was lower for kipping movements than for strict ones. The exception was the kipping PU, since among men the percentage of volunteers unable to perform kipping/butterfly PU was slightly greater than SPU, suggesting a deficiency in the technical aspects of this movement. Additionally, kipping BMU, RMU, and HSW were the "dynamic" movements (i.e. excluding the strict ones) with greater rates of inability (≥50%), suggesting the need for more attention by coaches. Conclusions. Our results allow reflecting upon coaches' approaches to teaching complex gymnastics-based exercises to persons without a gymnastic background, as well as reflecting upon further research to develop an understanding of interventions used to improve gymnastics-based exercises, transferring the key research findings into practice.

KEYWORDS: muscle strength, gymnastics, mixed modality training, calisthenics.

Received: 14 September 2022
Accepted: 9 January 2023

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Introduction

High-intensity functional training (HIFT) is defined as an exercise modality involving functional, multi-joint movements, adaptable to any fitness level [4], and comprises the basis of world-renowned programs such as CrossFit™, among others [3, 12]. Its growing popularity is undeniable, with scientific interest in this exercise modality simultaneously increasing [4, 5, 21]. Endurance-based exercises such as running, cycling, and rowing are merged with powerlifting, weightlifting, and gymnastics, performed in a continuous circuit or interval format and conducted at a high intensity [4]. This characteristic design justifies the recent use of the term "mixed modality training" (MMT) [5, 15] to designate this training methodology and, among the cited modalities, gymnastics exercises stand out as the most complex ones.

Indeed, artistic gymnastics comprises complex movements and requires adaptations to take part in HIFT workouts. For example, the ring muscle-up (RMU), one of the most complex gymnastics-based movements in the HIFT workouts, is an adaptation of the movement called "front uprise" in artistic gymnastics (for more details see [23]). RMU execution requires high-level motor skills, such as strength, temporal and spatial orientation, and coordination, which is difficult, but not impossible, to achieve when someone has no previous experience in artistic gymnastics, as the majority of HIFT practitioners around the world.

Other gymnastics-based exercises included in HIFT workouts are pull-up (PU) and its variations (strict pull-up [SPU], kipping/butterfly PU, strict chest-to--bar [SCtB], kipping/butterfly CtB), strict (STtB) and kipping toes-to-bar (TtB), bar muscle-up (BMU), which are exercises performed when suspended from a bar, while RMU is performed when suspended from a pair of rings. The list of gymnastics-based exercises also includes handstand exercises, such as handstand hold, handstand push-up (HSPU), and handstand walk (HSW).

Despite the growing adherence to HIFT programs, owing to the greater sense of community [2, 24], and the fact that gymnastics-based exercises represent a relevant part of HIFT workouts, there are no previous studies investigating estimates of the prevalence of gymnastics-based movement ability/inability among HIFT practitioners.

The present study aimed to estimate the prevalence of the ability/inability to perform these gymnastics-based movements among HIFT practitioners.

Material and Methods

Study design and sampling

This is a descriptive study using a "virtual snowball" sampling method [13]. Conducted from October to December 2021 with HIFT practitioners, through an online questionnaire (appendix) sent by the internet (Instagram® and WhatsApp® platforms) and detailed instructions to volunteers were available on a website. The sampling is a non-probability virtual snowball type, where the volunteers recruit prospective volunteers through their social networks or social communities, which expands the sample like a snowball [13]. The questionnaire was developed using Google Sheets® and presented in Portuguese, thus the sample volunteers were Brazilians or Portuguese speakers around the world.

The purpose and procedures of the survey were explained on the first page of the online form and consent was obtained prior to completing the form. All procedures were approved by the local ethics committee (protocol #3.425.388) according to the Declaration of Helsinki.

Definitions of variables

The online form was developed by the authors and contains 34 questions divided into 5 sections: sociodemographic questions (n = 4), history of physical training (n = 8), personal records of gymnastics-based exercises applied in HIFT workouts (n = 14), perceived and/or measured gymnastic skills (n = 3), perceived and/or measured core endurance (n = 5), with an estimated time of 3 to 5 minutes to answer all questions

The personal records of gymnastics-based exercises applied in HIFT workouts comprised the following movement: PU and its variations (SPU, kipping/butterfly PU, SCtB, kipping/butterfly CtB), STtB and kipping TtB, BMU, which are exercises performed when suspended from a bar, while RMU is performed when suspended from a pair of rings. The list of gymnastics-based exercises also includes the handstand exercises, such as handstand hold, HSPU, and HSW.

Aiming to determine the prevalence of gymnastics-based movement ability/inability among HIFT practitioners, the data from personal records of gymnastics-based exercises applied in HIFT workouts were dichotomized as "Yes", when the volunteer reported being able to complete the specific movement (e.g. BMU), and "No", when the volunteer reported being unable to do it. For handstand hold the parameter was established as "Yes", when the volunteer reported being able to sustain this position for more than 5 seconds with the body aligned (freestanding, without wall support), and for HSW the parameter was established as "Yes", when the volunteer reported being able to walk for at least 1 meter unbroken.

Considering that men tend to be naturally stronger than women [17] and many gymnastics-based movements depend on strength, all descriptive data were analyzed for the total sample and stratified by sex.

Statistical analysis

The dichotomized data concerning the ability/in-ability of gymnastics-based movements were analyzed descriptively using absolute and relative (i.e. percentage) frequency. Continuous data (e.g. age) from sociodemographic recordings were presented as mean ± standard deviation.

Results

A total of 1325 volunteers (men: 587; women: 738) answered the survey; the mean age of volunteers was 30.8 ± 7.1 (min: 12, max: 71) years old (men: 30.7 ± ± 7.0, min: 14, max: 67; women: 31.0 ± 7.2, min: 12, max: 71 years old). A quarter of volunteers (24.5%; men: 22.8%, women: 25.8%) reported having less than one year of HIFT experience, 39.9% (men: 38.5%, women: 41.0%) reported having one to three years of practice, and 35.6% (men: 38.7%, women: 33.2%) more than three years of practice.

We found 76.4% of volunteers (n = 1325) able to complete at least one SPU, while 52.8% were able to complete SCtB. Considering the kipping and butterfly variations, the prevalence of volunteers able to perform them was 80.7% for PU, and 64.9% for CtB (Table 1). When the sample was stratified according to sex, we found different profiles between women and men. The prevalence of women able to perform strict exercises was lower than men. We found that 61.7% and only 29.9% of women were able to perform SPU and SCtB, respectively, while among men the prevalence was 95.1% and 81.7%, respectively. Considering the same movements, but using kipping/butterfly technique, the prevalence among women was 71.4% and 49.4% for PU and CtB, whereas among men it was 92.5% and 84.5% for PU and CtB, respectively (Table 1).

Table 1. Prevalence of volunteers (n = 1325) stratified by sex (women = 738; men = 587) able to do strict and kipping/butterfly pull-up and chest-to-bar pull-up

	Strict pull-up		
	All	Women	Men
No	23.6%	38.3%	4.9%
Yes	76.4%	61.7%	95.1%
	Kipping/butterfly pull-up		
	All	Women	Men
No	19.3%	28.6%	7.5%
Yes	80.7%	71.4%	92.5%
	Strict chest-to-bar		
	All	Women	Men
No	47.2%	70.1%	18.2%
Yes	52.8%	29.9%	81.7%
	Kipping/butterfly chest-to-bar		
	All	Women	Men
No	35.1%	50.6%	15.5%
Yes	64.9%	49.4%	84.5%

The prevalence of volunteers able to complete at least one STtB was 62.1%, while only 10.2% and 14.1% were able to complete at least one strict BMU and strict RMU, respectively. Using kipping, 81.2%, 42.1%, and 27.5% of volunteers reported being able to complete at least one TtB, BMU, and RMU, respectively (Table 2). For STtB, strict BMU and RMU the prevalence of women able to do each movement was 44.8%, 3.8%, and 6.1%, respectively, while for men it was 83.9%, 18.3%, and 24.2%, respectively. Considering the same movements, but using the kipping technique, the prevalence among women was 71.0%, 20.4% and 10.2% for TtB and BMU and RMU, and among men it was 94.0%, 69.4%, and 49.3% for TtB and BMU and RMU, respectively (Table 2).

Table 2. Prevalence of volunteers (n = 1325) stratified by sex (women = 738; men = 587) able to do strict and kipping toes-to-bar, bar muscle-up (BMU) and ring muscle-up (RMU)

	Strict toes-to-bar		
	All	Women	Men
No	37.9%	55.2%	16.1%
Yes	62.1%	44.8%	83.9%
	Kipping toes-to-bar		
	All	Women	Men
No	18.8%	29.0%	6.0%
Yes	81.2%	71.0%	94.0%
	Strict BMU		
	All	Women	Men
No	89.8%	96.8%	81.7%
Yes	10.2%	3.8%	18.3%
	Kipping BMU		
	All	Women	Men
No	57.9%	79.6%	30.6%
Yes	42.1%	20.4%	69.4%

	Strict RMU		
	All	Women	Men
No	85.9%	93.9%	75.8%
Yes	14.1%	6.1%	24.2%
	Kipping RMU		
	All	Women	Men
No	72.5%	89.8%	50.7%
Yes	27.5%	10.2%	49.3%

Table 3 presents the results from handstand exercises, indicating that 60.5% of volunteers were able to complete at least one strict HSPU and 72.1% were able to complete kipping HSPU. The prevalence of volunteers able to maintain more than 5 seconds of handstand hold was 51.1%, while only 31.2% were able to walk at least 1 meter in the handstand position.

Regarding the handstand exercises, 45.3% of women and 79.7% of men volunteers were able to perform strict HSPU, while 61.3% of female and 85.7% of male volunteers were able to perform kipping HSPU. For the handstand hold, 42.1% of women and 62.5% of men volunteers were able to maintain more than 5 seconds of the handstand hold, while for HSW only 15.0% of women and 51.8% of men volunteers were able to walk at least 1 meter (Table 3).

Table 3. Prevalence of volunteers (n = 1325) stratified by sex (women = 738; men = 587) able to do strict and kipping handstand pushup (HSPU), handstand hold, and handstand walk (HSW)

	Strict HSPU		
	All	Women	Men
No	39.5%	54.7%	20.3%
Yes	60.5%	45.3%/	79.7%
	Kipping HSPU		
	All	Women	Men
No	27.9%	38.7%	14.3%
Yes	72.1%	61.3%	85.7%
	Handstand hold		
	All	Women	Men
No	48.9%	57.9%	37.5%
Yes	51.1%	42.1%	62.5%
	HSW		
	All	Women	Men
No	68.8%	85.0%	48.2%
Yes	31.2%	15.0%	51.8%

Discussion

The present study aimed to estimate the prevalence of gymnastics-based movement ability/inability among HIFT practitioners, and our results allowed us to identify a relatively high prevalence of practitioners unable to perform strict movements, especially BMU and RMU, an inability that was more prominent among female practitioners. The prevalence of practitioners unable to perform HSW was also high, especially among women. Performance in artistic gymnastics routines is linked to strength (static strength, muscle power in the lower and upper limbs), flexibility, and muscular anaerobic endurance [1, 30]. Indeed, static strength is the basis of gymnastics training [25], since it is essential in artistic gymnastics routines, as well as gymnastics-based exercises applied in HIFT workouts [27]. Sommer [25] stated that basic strength, which involves the ability to develop maximal strength at fundamental static positions with bodyweight resistance, is the initial building block, from which all other gymnastics training progresses. In the context of HIFT, these fundamental static positions should be interpreted as SPU, SCtB, STtB, strict BMU, strict RMU and HSPU.

In our study the prevalence of inability to perform at least one repetition of strict movements was high, which represents a barrier to the progress of gymnastics skills, impacting the HIFT workouts progress when gymnastics--based movements are included. Strict BMU and RMU exhibited the highest prevalence of inability with 89.8% and 85.9% of volunteers unable to perform these movements, respectively. Among the strict movements, BMU and RMU were the ones with lower percentage differences between men and women, indicating they were the main deficit, at least in the context of maximal strength, among HIFT practitioners independent of sex. In this context, two aspects should be highlighted: 1) in artistic gymnastics the rings are used exclusively by men, while in HIFT workouts there are no general rules limiting women to perform RMU; 2) despite the high inability to perform strict BMU (89.8%) and RMU (85.9%), the prevalence of inability to perform the cited movements using kipping was relatively lower, 57.9% and 72.5%, corresponding to a difference of 35.5% and 15.5% of volunteers that were unable to perform the strict BMU and RMU, respectively, but were able to perform these movements using kipping as a technique. Thus, it is possible that the "maximal strength at fundamental static positions" could account for a small part of the factors that influence/determine the ability to perform kipping BMU and RMU, then using the kipping effectively could help to achieve the movement, despite the inability to perform the strict BMU and RMU.

In time, it is also worthwhile to highlight that the relevance of maximal strength should not be excluded as a determinant of kipping BMU and RMU success, since men, who are generally stronger than women, exhibited a greater discrepancy in the percentage of volunteers reporting that they were unable to perform strict BMU and RMU, but able to perform kipping BMU and RMU.

Another interesting aspect to be discussed in the context of technique was the very similar percentage of inability to perform strict BMU and RMU (BMU = 89.8%; RMU = 85.9%; difference = 3.6% greater for BMU), but a considerable discrepancy in the percentage of inability to perform kipping BMU and RMU (BMU = 57.9%; RMU = 72.5%; difference = 14.6% greater for RMU), suggesting the RMU demands greater technique skills. The characteristics of used implements (i.e. bar vs rings) in each movement (BMU vs RMU) could explain this discrepancy, since the bar is a fixed implement, while rings are a mobile implement, demanding greater abilities to control it. Indeed, Santos Rocha et al. [23] discussed the complexity of RMU as a gymnastics--based exercise, and our results corroborate this fact.

The STtB is similar to the hanging leg lifts (HLL) in artistic gymnastics that demand great core strength, requiring specific core strengthening routines, commonly applied by artistic gymnastics, to perform this movement. In our study, 37.9% of volunteers reported being unable to perform at least one STtB. As the HLL is a mandatory component in gymnastic athletes' training programs [25], our result from STtB suggests that HIFT practitioners are not prioritizing the specific core strength training as the artistic gymnastics. Despite the peculiarities of each modality (i.e. artistic gymnastics vs HIFT), core strength seems to be a common skill required for high performance in both modalities [6, 9, 25].

The kipping TtB is a gymnastics-based movement with close technical aspects to kipping BMU and RMU, especially the former one. Like kipping BMU and RMU, the kipping TtB consists of two main phases, the "arch", and "hollow" position. During the kipping BMU and RMU the hollow position is changed with an abrupt hip extension, projecting the hip vertically (see Santos Rocha et al. [23]), whereas during the kipping TtB the hollow position is sustained, progressing with a greater hip flexion aiming to touch the bar with toes. The discrepancy between the percentage of volunteers unable to perform STtB (37.9%) and kipping (18.8%) TtB also indicates that an adequate technique use of kipping could help to achieve the moment, despite the core strength limitations indicated by the inability to perform STtB.

When stratified by sex, our results reveal a greater limitation among women than men to perform STtB (women: 55.2% vs men 16.1% unable to perform the movement) and kipping (women: 29.0% vs men 6.0%) TtB. These data emphasize the need to develop specific strategies to improve core strength, more specifically the engagement and synergy of core and lat muscles, and technical skills for women, aiming to achieve the TtB movement.

The pull-up and its variation, the CtB pull-up are commonly used gymnastics-based exercises in HIFT workouts [16, 29]. In the pull-up the aim is to pull the body from the hanging position (i.e. the body completely extended), aiming for the chin to reach the bar height with the elbows flexed at ~90º [19, 26], while in the CtB the aim is to pull to touch the bar with the chest, requiring a greater vertical displacement, thus also a greater effort. The SPU and SCtB are multi-joint upper-body exercises that are considered valid measures of weight relative to muscular strength [19, 22, 26], in the same sense they are used to improve the upper limb strength when included in gymnastics training routines [25]. Our results show that 23.6% of volunteers reported being unable to perform at least one SPU, and 47.2% were unable to perform a SCtB, a high prevalence of inability to perform two basic exercises in the gymnastic context. As expected the inability was greater among women (SPU: 38.3%; SCtB: 70.1%) than men (SPU: 4.9%; SCtB: 18.2%), since 70.1% of women reported being unable to perform SCtB. Interestingly, the discrepancy between the inability to perform SPU and kipping/butterfly pull-up was very similar, which was also observed for SCtB and kipping/butterfly CtB.

Indeed, kipping/butterfly pull-ups (PU) require a complex technique [7, 20, 29] and our results corroborate this fact. Among men, who are typically stronger than women, the pull-up was the unique movement with the percentage of volunteers unable to perform the strict movement being lower than with the execution with technique (i.e. kipping/butterfly) (SPU: 4.9% vs kipping/butterfly PU: 7.5%; difference = 2.6% greater for kipping/butterfly PU). It means that kipping/butterfly pull-ups are less dependent on strength and more dependent on technique skills.

The upside-down position, such as the handstand, is not easy to achieve and sustain, because it requires 1) courage, since many persons fear falling being submitted to this position [18], 2) strength to sustain the body weight over the upper limbs [10], 3) good spatial orientation since vestibular, visual and plantar somatosensorial inputs are not reliable/congruent [14]. These requirements could help to explain why 48.9% (57.9% among women and 37.5% among men) of volunteers were unable to sustain more than 5 seconds of a handstand hold. Curiously, the static handstand hold is an essential technique needed to progress to more complex tasks in the context of artistic gymnastics [8].

Regarding strict HSPU, an upper-body, multi-joint exercise designed to increase upper extremity, shoulder, and core stability [11], we found that 39.5% of volunteers reported being unable to perform at least one repetition, indicating a deficiency in strength for an essential pushing task. As expected, the limitation was greater among women than men (54.7% vs 20.3% unable to perform strict HSPU). The use of a kipping technique allowed more volunteers to perform the HSPU, since 27.9% reported being unable to perform at least one repetition of kipping HSPU. Interestingly, the technique seems to favor women to perform the HSPU, since the percentage difference of inability between strict HSPU and kipping HSPU was greater (54.7% minus 38.7% = = 16%) among women than among men (20.3% minus 14.3% = 6%).

The HSW requires the same skills as the handstand hold, adding the fact that the HSW is a dynamic task, which imposes an additive challenge [28]. Thus, this explains the greater percentage of inability to walk at least 1 meter in an upside-down position (i.e. HSW) (68.8%) when compared to the percentage of inability to sustain more than 5 seconds in handstand hold (48.9%). In addition, the rate of inability to perform HSW was greater among women (85.0%) than men (48.2%), drawing attention to the need for an adequate amount of time applied to learn/train this movement, as well as adequate classes to allow adequate technique skill acquisition.

Strengths and limitations

This study provides a detailed descriptive insight into the rate of gymnastics-based movement ability/inability among HIFT practitioners. However, the limitations of the present study should be recognized. This study only included HIFT practitioners from Brazil or Portuguese speakers around the world, and the rates could diverge from countries with a historical culture of artistic gymnastics for children, where the early experience with gymnastics is probably greater. Additionally, this is a cross-sectional study, and the data were recorded through an online survey, thus the precision of reports could not be always guaranteed. Despite this, it should be noted that the sample size of this study was relatively large.

Conclusions

We presented a complete overview of the prevalence of ability/inability to perform gymnastics-based movements among HIFT practitioners. As strict movements are essential for artistic gymnastics, the high rate of inability in these essential movements, for instance, SPU, SCtB, STtB, strict HSPU, strict BMU, and strict RMU, draws attention to the need for additional (i.e. separate) strength training, valuing static strength training of gymnastics-based movements. Additionally, kipping BMU, RMU, and HSW were the “dynamic” movements (i.e. excluding the strict ones) with greater rates of inability (all with more than 50% of inability reported), suggesting the need for more attention within HIFT workouts.

Acknowledgements

The authors thank all volunteers who answered the online survey and help to share as proposed by the “snowball” method. The authors also thank all IRC staff, Dr. Rodrigo Jasbick, and Axel Gouveia for their value considerations throughout the project development.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Atikovic A, Kalinski SD, Čuk I. Age trends in artistic gymnastic across world championships and the olympic games from 2003 to 2016. Sci Gymnast J. 2017;9:251-263.
2. Bycura D, Feito Y, Prather C. Motivational factors in CrossFit® training participation. Health Behav Policy Rev. 2017;4:539-550.
3. Falk Neto J, Kennedy M. The multimodal nature of high--intensity functional training: potential applications to improve sport performance. Sports. 2019;7:33.
4. Feito Y, Heinrich K, Butcher S, Poston W. High-intensity functional training (HIFT): definition and research implications for improved fitness. Sports. 2018;6:76.
5. Figueiredo R, Pereira R, Neto OP. Nonlinear analysis is the most suitable method to detect changes in heart autonomic control after exercise of different durations. Comput Biol Med. 2018;97:83-88.

6. Glassman G. The CrossFit level 1 training guide. CrossFit. 2020.
7. Glassman G. The kipping pull-up. Crossfit Journal. 2005;32:1-3.
8. Grabowiecki M, Rum L, Laudani L, Vannozzi G. Biomechanical characteristics of handstand walking initiation. Gait Posture. 2021;86:311-318.
9. Haddock CK, Poston WSC, Heinrich KM, Jahnke SA, Jitnarin N. The benefits of high-intensity functional training fitness programs for military personnel. Mil Med. 2016;181:e1508-e1514.
10. Hedbávný P, Bago G, Kalichová M. Influence of strength abilities on quality of the handstand. Int J Sport Health Sci. 2013;7(10):602-608.
11. Johnson A, Meador M, Bodamer M, Langford E, Snarr RL. Exercise technique: handstand push-up. Strength Cond J. 2019;41:119-123.
12. Júnior JLNS, Passos R da S, Oliveira AA, da Silva JRD, Souza RS, Passos R de S, et al. The influence of hand guards on explosive force and pain and exertion perception in a hang holding task. Sci Gymnast J. 2021;13:107-117.
13. Kirchherr J, Charles K. Enhancing the sample diversity of snowball samples: recommendations from a research project on anti-dam movements in Southeast Asia. PLoS One. 2018;13:e0201710.
14. Kochanowicz A, Kochanowicz K, Niespodzinski B, Mieszkowski J, Biskup L. The level of body balance in a handstand and the effectiveness of sports training in gymnastics. Balt J Health Phys Act. 2015;7(4):11.
15. Marchini A, Pereira R, Pedroso W, Christou E, Neto OP. Age-associated differences in motor output variability and coordination during the simultaneous dorsiflexion of both feet. Somatosens Mot Res. 2017;34:96-101.
16. Martínez-Gómez R, Valenzuela PL, Alejo LB, Gil-Cabrera J, Montalvo-Pérez A, Talavera E, et al. Physiological predictors of competition performance in crossfit athletes. Int J Environ Res Public Health. 2020;17:1-12.
17. Nuzzo JL. Narrative review of sex differences in muscle strength, endurance, activation, size, fiber type, and strength training participation rates, preferences, motivations, injuries, and neuromuscular adaptations. J Strength Cond Res. 2022:37(2):494-536. https://doi.org/10.1519/JSC.0000000000004329
18. Omorczyk J, Zajac A, Puszczalowska-Lizis E. Relationships between postural stability in standing and handstand and psychological factors in athletes practicing artistic gymnastics. Balt J Health Phys Act. 2019;11(4):11.
19. Pate RR, Burgess ML, Woods JA, Ross JG, Baumgartner T. Validity of field tests of upper body muscular strength. Res Q Exerc Sport. 1993;64:17-24.
20. Prinold JAI, Bull AMJ. Scapula kinematics of pull-up techniques: avoiding impingement risk with training changes. J Sci Med Sport. 2016;19:629-635.
21. Pritchard HJ, Keogh JW, Winwood PW. Tapering practices of elite CrossFit athletes. Int J Sports Sci Coach. 2020;15:753-761.
22. Ronai P, Scibek E. Exercise technique the pull-up. Strength Cond J. 2014;36:88-90.
23. Santos Rocha JA, Pereira G, Kilipper R, Pereira J, Barsanulfo S, Castro FB, et al. Influence of key-points of ring muscle-up execution on movement performance: a descriptive analysis. Cent Eur J Sport Sci Med. 2020;29:41-51.
24. Simpson D, Prewitt-White TR, Feito Y, Giusti J, Shuda R. Challenge, commitment, community, and empowerment: factors that promote the adoption of crossfit as a training program. Sport J. 2017;1:1-14.
25. Sommer C. Building the gymnastic body: the science of gymnastics strength training. Anthem: Olympic Bodies, LLC; 2008.
26. de Sousa AFM, dos Santos GB, dos Reis T, Valerino AJR, del Rosso S, Boullosa DA. Differences in physical fitness between recreational CrossFit® and resistance trained individuals. J Exerc Physiol. 2016;19.
27. Tibana RA, Neto IV de S, de Sousa NMF, Romeiro C, Hanai A, Brandão H, et al. Local muscle endurance and strength had strong relationship with CrossFit® Open 2020 in amateur athletes. Sports (Basel). 2021;9:98.
28. Uzunov V. The handstand: a four stage training model. Gym Coach. 2008;2:52-59.
29. Williamson T, Price P. A comparison of muscle activity between strict, kipping and butterfly pull-ups. J Sport Exer Sci. 2021;5:149-155.
30. Zasada S, Zasada M, Kochanowicz A, Niespodzinski B, Sawczyn M. The effect of specific strength training on the quality of gymnastic elements execution in young gymnasts. Balt J Health Phys Act. 2016;8:79-91.

ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**1**): 21-28
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.1-3

Reference interval for oxidative stress markers in young football and hockey players

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Abstract
Introduction. **Malondialdehyde (MDA), superoxide dismutase (SOD), glutathione (GSH), and glutathione peroxidase (GPx) are widely accepted as biological markers for checking the redox balance and antioxidant status.** Aim of Study. **The purpose of the study was to frame the reference interval for antioxidant variables (MDA, SOD, GSH and GPx) in the young athletic population of various sports discipline.** Material and Methods. **190 young male players [i.e., football (n = 89), and hockey (n = 101)] were recruited for the study (mean age = 18.3 ± 2.01 yrs). Assay of MDA, SOD, GAH and GPx was done by using the standard enzymatic protocol. Reference interval was calculated by following the Clinical and Laboratory Standard Institute (CLSI) C28-A3 guideline and MedCalc software (version 19) with a 90% confidence interval.** Results. **Serum MDA range was from 23.75-36.19 µmoles/100ml serum with mean of 30.29 ± ± 3.24 µmoles/100 ml serum and median around 30.43. Serum SOD ranged from 0.05-0.14 U/min/mg protein with mean of 0.08 ± 0.01 U/min/mg protein and median around 0.08. The GSH was ranging from 43.21-55.55 mg/100 ml serum with mean of 46.43 ± 2.11 mg/100 ml serum and median around 46.10. The GPx was ranging from 9.04-14.33 µmol/min/mg protein with mean of 11.35 ± 1.38 µmol/min/mg protein and median around 11.05.** Conclusions. **Present study confers 24.55--35.58 µmoles/100 ml serum, 0.06-0.13 U/min/mg protein, 43.27--51.86 mg/100 ml serum, and 9.07-14.12 µmol/min/mg protein as the reference interval values for MDA, SOD, GSH, and GPx respectively. The present finding will guide the researchers to avoid misinterpretation of antioxidant biomarker values during any phase of competitive training of sports person.**

KEYWORDS: lipid peroxidation, glutathione, reference interval, antioxidant biomarkers, endurance team-game.

Received: 30 August 2022
Accepted: 13 March 2023

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Introduction

An exercise-induced oxidative stress condition following a high-intensity training session was (i.e., eccentric or reaped works) hypothesized to be metabolic, mechanical or both in nature during the temporary hypoxic condition that leads to excess reactive oxygen species (ROS) generation [17, 23]. The exercise-induced overproduction of ROS creates oxidative stress and challenge redox equilibrium, which further disrupts cellular homeostasis and leads to a rise in lipid peroxidation [13, 23]. The presently studied summary data of MDA, SOD, GSH, and GPx in reference to endurance team-games such as football and hockey have no game specific references in terms of antioxidant variables, which might due to the nature of energy requirements for the game and the high demand of recovery with a higher level of endurance capacity with a high burst of intense energy for short running sprints [1, 17]. However, a single high-intensity exercise and/or even a long duration moderate-high intensity training of endurance team-game such as football and hockey were observed to induce oxidative stress via altering antioxidant biomarker enzymes and thus can lead to redox imbalance [1, 14, 17]. The present study can help to monitor the overreaching/overtraining condition of athletes by observing the resting data via comparing them with well-defined reference intervals of antioxidant biomarkers (i.e., MDA, SOD, GSH, and GPx). This can ultimately lead to ROS induced damage to muscle and create exercise-induced fatigue, which might limit sports performance.

Reference interval (RI) is a range of values for a certain parameter that is deemed to be normal or within the physiological limit for that particular population in that particular condition [10]. Preventing misinterpretation of any biochemical data can only be possible based on RI studies [16]. Interval values can be altered depending on the population variation such as e.g. sports palyers, healthy sedentary persons and patients, since all may have different reference intervals for a given parameter in the resting condition. Brancaccio et al. [2] reported an enzymatic alteration following adaptations to physical training, including the training volume and intensity. Standardized RI will help to assess the effect of training through blood biomarkers, which must be previously established in a specified group of the population [16].

There were very few studies which predicted RI values for CK [12, 18] and LDH [18, 22] for an athletic population. Studies such as e.g. Mahmutyazicioglu et al. [12] differentiated reference values for the normal population from the athletic population. However, to date, there have been no studies of reference intervals for antioxidant biomarkers and in terms of the athletic population there is a huge gap. Only an unclear prediction can be made based on some of the studies, where initial data of antioxidant variables was present, although all of them originate either from the study of training intervention [17, 24], nutritional intake profiling [6, 7], or a generalized profile study [5]. More importantly, none of those studies were aimed for reference intervals of antioxidant variables. Additionally, all those previous studies only included very small athlete numbers which restricts their effectiveness and as a result they may not be a source of reference ranges. The reference range values for important biomarkers such as MDA, SOD, GSH and GPx will provide an insight into oxidative stress responses against the exercising/training induced damaging condition of muscles, which might be accompanied by hampering inflammatory responses. All together the antioxidant enzymatic biomarker alteration and redox equilibrium imbalance could help to predict the indirect fatigue limit of physical functioning and the overtraining/overreaching condition. Thus, the present study was aimed at identifying reference intervals for antioxidant biomarkers (i.e., MDA, SOD, GSH and GPx) among young athletes practicing football and hockey.

Material and Methods

Subjects

A total of 190 young male state level athletes (mean age = 18.3 ± 2.01 yrs) of 2 endurance-based team-games, i.e., football (FB, n = 89), and hockey (HOC, n = 101), were recruited as subjects for the present cross-sectional study. All participants had a minimum 4 years of formal training history and had played at minimum state-level competition. Players were considered to be homogeneous in terms of the socio-economic group, dietary habits and identical environmental conditions during training sessions. Subjects were clinically examined before commencing the study and only fit players were chosen as the study subjects. During the present study, all the players were in the pre-competitive training phase. The ethical guidelines of Helsinki's Declaration were maintained throughout the study protocol and written informed consent was also obtained from each subject. Proper ethical clearance (Ref No. IHEC/AB/P82/2019) was also obtained from the Institutional Human Ethical Committee (IHEC), Department of Physiology, University of Calcutta.

Training regimen

Players of both the games were trained for 5 hours/day, which was further divided into 2:30 hours in equal halves of morning and evening sessions daily excluding Sundays. Thus, the weekly training volume amount to approx. 30 hours/week. The players were at the early pre-competitive phase where maintenance was conducted with a training load of work : rest = = 1 : 1. Strength training sessions were performed twice a week and endurance training sessions were conducted once a week, although all the other sessions included 70-80% of game specific skill trainings supplemented with the physical training part where various interval running, shuttle runs, plyometrics, etc. were carried out. Game specific skill training includes ball bridling, goal practice, long/short pass practice, and training match play, etc.

Biochemical analysis

Process of blood collection and plasma sample preparation:

Venous blood samples were collected from the antecubital vein into centrifuge tubes for serum preparation (without anticoagulant) between 6:00 AM and 8:00 AM in the pre-prandial state (after 8-10 hours of fasting) to avoid possible differences due to diurnal variation. Each blood supernatant was centrifuged at 3000 rpm for 15 minutes to ensure complete separation of serum. The samples were then transferred into cryo-vials and stored and preserved at –20°C for later biochemical analyses [19]. All laboratory tests were performed at room temperature varying from 23ºC to 25ºC with the relative humidity of 50-60%.

Assays for antioxidant status variables (MDA, SOD, GSH and GPx):
Malondialdehyde (MDA) was measured by reacting with thiobarbituric acid (TBA) to form TBA-MDA under acidic conditions at an elevated temperature at 532 nm and expressed as moles of MDA/100 ml serum. Superoxide dismutase (SOD) was estimated by inhibiting the auto-oxidation of pyrogallol at 420 nm. The SOD activity was expressed as U/min/mg protein and 1 U of the enzyme is defined as the enzyme activity that inhibits auto-oxidation of pyragallol by 50%. Reduced glutathione (GSH) content was estimated from a yellow coloured complex after reacting to DTNB with an absorbance maximum at 412 nm expressed as mg/100 ml serum. The glutathione peroxidase (GPx) enzyme degrades H_2O_2 in the presence of GSH. The remaining GSH was measured via its reaction with DTNB. GPx activity was expressed as µmoles of GSH consumed/min/mg protein. All oxidative stress markers (MDA, SOD, GSH, GPx) were measured following the standard procedure [11, 17]. Protein levels were estimated following the Lowry method where the Folin–Ciocalteu reagent was used to produce a blue-purple coloured complex, with maximum absorption at 660 nm.

Statistical analysis
Statistical analysis was performed using the Statistical Program for Social Sciences (SPSS) version 18.0 for Windows (SPSS Inc., Chicago, IL, USA). All values were expressed as means ± standard deviation (SD). ANOVA was separately performed to assess the group--specific differences among MDA, SOD, GSH, and GPx. Descriptive statistics were also calculated, which included the mean, median, mode, standard deviation, standard error of the mean, range, percentile, etc. One sample Kolmogorov–Smirnov test and histogram were performed to check the frequency distribution of the data set. Approved guidelines of the Clinical and Laboratory Standard Institute (CLSI, C28-A3) and the International Federation of Clinical Chemistry (IFCC) were followed to identify the RI at the 95% confidence interval (CI). The G*Power software (version 3.1.9.7) was used for sample size calculation over the statistical test of one-way fixed effects ANOVA at 95% CI. The MedCalc software (version 19, MedCalc Software bvba) was used to calculate the reference intervals in the present study [3, 15, 20].

Results
Table 1 presents general anthropometry and antioxidant variables of young male athletes from various sports disciplines. All variables inducing anthropometry and antioxidant biomarker variables were found to show no game-specific significant differences when compared between football and hockey.

Table 1. Mean and standard deviation of general anthropometry and antioxidant variables of young male athletes of football and hockey sports discipline

Variables	Football (n = 89)	Hockey (n = 101)	t value	P value
Body height (cm)	167.77 ± 6.04	168.70 ± 4.97	–1.158	0.248 NS
Body weight (kg)	57.05 ± 6.98	59.42 ± 5.58	–2.591	0.010 NS
BMI	20.23 ± 1.86	20.85 ± 1.37	–2.650	0.009 NS
Fat%	14.36 ± 4.60	14.16 ± 5.53	0.261	0.794 NS
MDA (µmoles/100 ml serum)	30.00 ± 3.00	30.55 ± 3.44	–1.167	0.245 NS
SOD (U/min/mg protein)	0.08 ± 0.01	0.09 ± 0.02	–1.725	0.086 NS
GSH (mg/100 ml serum)	46.13 ± 1.36	46.70 ± 2.58	–1.852	0.066 NS
GPx (µmol/min/mg protein)	11.54 ± 1.36	11.19 ± 1.39	1.711	0.089 NS

Note: Values are expressed as mean ± SD; NS – non-significant, MDA – malondialdehyde, SOD – superoxide dismutase, GSH – glutathione, GPx – glutathione reductase

Table 2 represents descriptive statistics of antioxidant variables (i.e., MDA, SOD, GSH, and GPx) for the combined population of young male athletes. Here percentiles were only given at three points: 25%, 50% (median value) and 75%. MDA ranges from 23.75 to 36.19 µmoles/100 ml serum with a range of 12.44, for SOD it is 0.05-0.14 U/min/mg protein with a range of 0.09, GSH ranges from 43.21 to 55.55 mg/100 ml serum with a range of 12.34, while for GPx it is 9.04--14.33 µmol/min/mg protein with a range of 5.29, respectively.

Table 2. Descriptive statistics of oxidative stress variables for the combined group of young male endurance team-game athletes

		MDA	SOD	GSH	GPx
Mean		30.29	0.08	46.43	11.35
Median		30.43	0.08	46.10	11.05
Mode		30.55	0.07	45.20	11.05
Std. Deviation		3.246	0.016	2.113	1.385
Std. Error of Mean		0.235	0.001	0.153	0.100
Variance		10.53	0.00	4.46	1.91
Range		12.44	0.09	12.34	5.29
Minimum		23.75	0.05	43.21	9.04
Maximum		36.19	0.14	55.55	14.33
Percentiles	25%	28.02	0.07	45.13	10.32
	50%	30.43	0.08	46.10	11.05
	75%	33.19	0.10	47.59	12.20

Note: MDA – malondialdehyde, SOD – superoxide dismutase, GSH – glutathione, GPx – glutathione reductase, Std. Deviation – standard deviation, Std. Error of Mean – standard error of mean

Table 3 depicts reference intervals for MDA, SOD, GSH, and GPx in the combined group (n = 190) and in the individual game-specific populations. Reference intervals were calculated with a 90% confidence interval limit for all the sport disciplines. Reference intervals of the total athletic population/combine group were calculated using the non-parametric percentile method and individual sports-specific groups using the robust method (CLSI guideline, C28-A3). Reference intervals in the combined group for MDA, SOD, GSH and GPx were 24.55-35.58 µmoles/100 ml serum, 0.06-0.13 U/min/mg protein, 43.27-51.86 mg/100 ml serum, and 9.07-14.12 µmol/min/mg protein, respectively. Reed's method was applied for the outlier measurement and GSH only has three outlier measures.

The following figures [1(A), 1(C), 1(E), 1(G)] represent histograms for MDA, SOD, GSH and GPx, respectively. On the other hand, figures [1(B), 1(D), 1(F), 1(H)] show the Box-and-Whisker plots of MDA, SOD, GSH and GPx, respectively, for the median, lower quartile, upper quartile, lower extreme and upper extreme values. Histogram data show MDA (mean = = 30.29, Std. Dev. = 3.246); SOD (mean = 0.08, Std. Dev. = 0.016), GSH (mean = 46.43, Std. Dev. = 2.114), and GPx (mean = 11.36, Std. Dev. = 1.385).

Discussion

Functional and non-functional overreaching may result from physical training. Physical activity alters the antioxidant status in an athlete's body and MDA, SOD, GSH, GPx serve as biomarkers to monitor the athlete's antioxidant status and redox equilibrium [13,

Table 3. Reference interval for oxidative stress variables of young male athletes of football and hockey sports discipline

Variable wise reference interval			Combine (n = 190)	Football (n = 89)	Hockey (n = 101)
MDA (µmoles/100 ml serum)	Reference interval		24.55-35.58	23.82-35.87	23.75-37.50
	90% CI	lower limit	24.30-25.38	23.05-24.65	22.85-24.67
		upper limit	35.22-36.19	34.97-36.77	36.71-38.36
SOD (U/min/mg protein)	Reference interval		0.06-0.13	0.05-0.11	0.04-0.11
	90% CI	lower limit	0.05-0.06	0.04-0.05	0.04-0.05
		upper limit	0.10-0.14	0.10-0.11	0.11-0.12
GSH (mg/100 ml serum)	Reference interval		43.27-51.86	43.26-48.82	41.03-51.45
	90% CI	lower limit	43.21-43.50	42.78-43.70	39.98-42.17
		upper limit	49.30-55.55	48.29-49.24	50.36-52.47
GPx (µmol /min/mg protein)	Reference interval		9.07-14.12	8.64-14.17	8.24-13.91
	90% CI	lower limit	9.07-9.29	8.29-9.02	7.85-8.57
		upper limit	14.02-14.33	13.66-14.63	13.33-14.35

Note: MDA – malondialdehyde, SOD – superoxide dismutase, GSH – glutathione, GPx – glutathione reductase, 90% CI – 90 percentage confidence interval

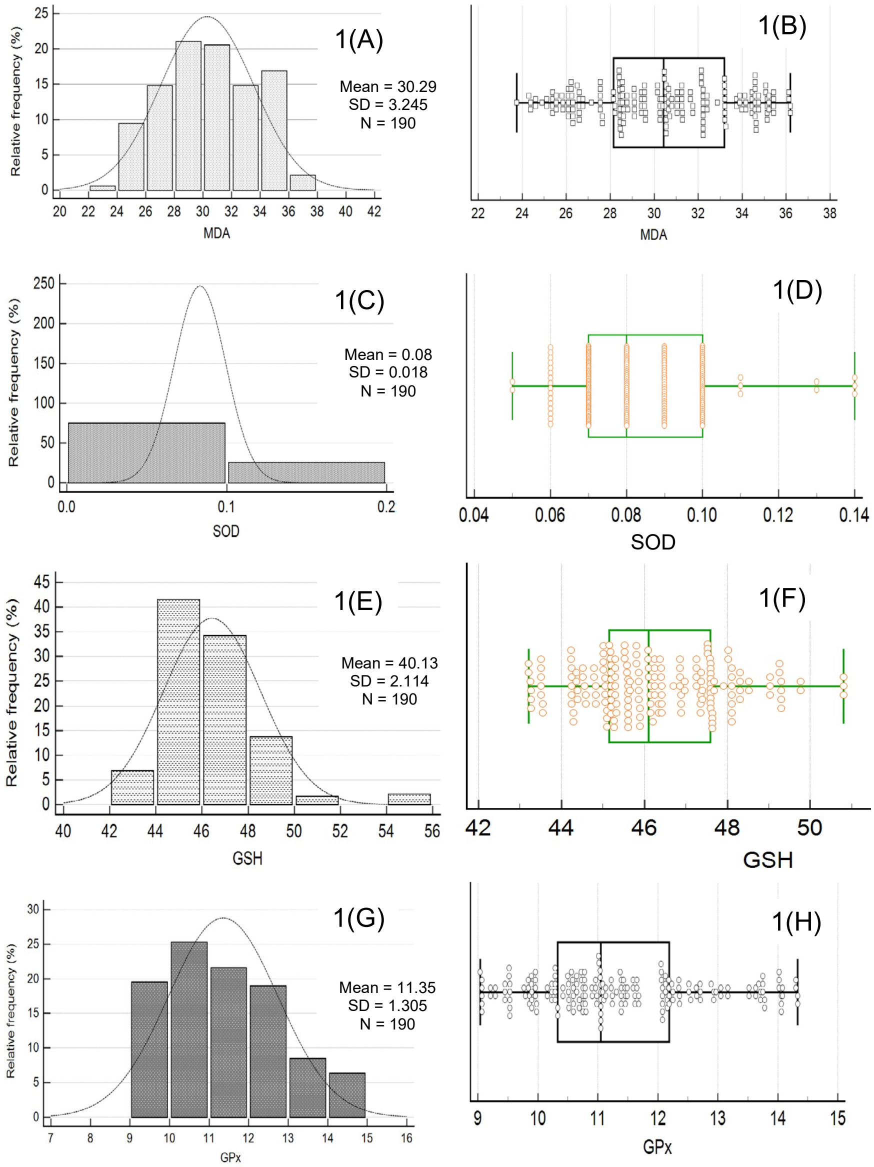

Figure 1. Representing histogram (A, C, E, G) and Box-and-Whisker plot (B, D, F, H) of MDA, SOD, GSH and GPx, respectively

17, 23]. Elevated SOD and GPx activities along with a reduced GSH level were assumed as the indication of oxidative stress specially when associated with a rise in the MDA level. An excessive training load and training intensity results in exercise-induced oxidative stress via ROS generation leading to redox equilibrium imbalance [13, 23]. Sometimes the altered antioxidant status during the oxidative stress condition of overtraining/overreaching was reported to be associated with limiting and/or hampering the physical performance [4, 9, 23]. Thus, to establish the reference intervals of antioxidant variables is crucial for the resting range of antioxidant status and to maintain the same for endurance team-game athletes.

In the present study, the 95% RI ranges for muscle damaged indices (i.e., MDA, SOD, GSH, and GPx) of all athletes (n = 190) were calculated following the guidelines of IFCC and CLSI (C28-A3) of the non--parametric percentile method (CLSI standard C28-A3) using reference limits at the 0.025 fractile (2.5th percentile) for the lower reference limit and 0.975 fractile (97.5th percentile) as the upper reference limit. Data were transformed to the Gaussian distribution using the Box–Cox transformation and then outliers were detected and removed using Dixon’s method [22]. However, for individual groups (i.e., football, hockey) the interval was calculated according to the ‘robust method’, as those groups had a smaller sample size (<120) [3, 8]. One sample Kolmogorov–Smirnov test clarifies the distribution of data set and depicts statistical significance values (2 tailed) for MDA, SOD, GSH, and GPx. Skewness and kurtosis were for MDA (0.009, –1.036), SOD (0.780, 1.315), GSH (1.725, 5.512), and GPx (0.455, –0.605), respectively, whereas the Kolmogorov–Smirnov test, histogram and the Box-and-Whisker plot show that MDA has a normal frequency distribution.

In the present study, the RI of resting serum MDA was 24.55-35.58 μmoles/100 ml serum with the mean of 30.29 ± 3.24 and the median around 30.43. The RI of resting serum SOD was 0.06-0.13 U/min/mg protein with the mean of 0.08 ± 0.016 IU/L and the median around 0.08. In turn, the RI of resting serum GSH was 43.27--51.86 mg/100 ml serum with the mean of 46.43 ± 2.11 and the median around 46.10. The RI of resting serum GPx was 9.07-14.12 μmol/min/mg protein with the mean of 11.35 ± 1.38 and the median around 11.05. Present studied RI data was in agreement with the report of Sarkar et al. [17], where control group data falls into the presently discussed reference ranges of antioxidant variables. Excess high intensity exercise or overtraining leads to a temporary hypoxic condition, which includes the overproduction of ROS, induces oxidative stress and challenges redox equilibrium, further disrupting cellular homeostasis and leading to increased lipid peroxidation [13, 23]. Excess ROS generation mainly occurs in the mitochondria and diffuses into the cytoplasm, where as a result a molecular cascade is initiated, which involves AMP-activated protein kinase (AMPK), proliferator activated receptor-gamma (PPARγ), PPARγ coactivator--1α (PGC-1α), etc. [25].

Several studies such as e.g. Miyazaki et al. [14], Azizbeigi et al. [1], and Metin et al. [13] reported that even a single bout of intense exercise can alter the antioxidant equilibrium and induce lipid peroxidation with an increased MDA level. According to Sarkar et al. [17], high-intensity training (HIIT for 8 weeks) commonly used during the preparatory phase might lead to a significant rise in oxidative stress indicated by increased levels of MDA, SOD, GSH, and GPx biomarkers along with muscle damage and inflammation. Additionally, Sousa et al. [21] by summarizing 38 studies reported that pro-oxidants, i.e., TBARS/MDA, PC, myeloperoxidase and H_2O_2, etc. tend to decrease significantly in association with an increase in SOD, GPx, catalase, TAC and GSH as a physical training-induced effect. On the other hand, Sarkar et al. [17] reported a significant positive correlation of maximal oxygen consumption ($\dot{V}O_{2max}$) and explosive strength with MDA and a significant negative correlation of $\dot{V}O_{2max}$, anaerobic power and explosive strength with the GSH level. All those previous studies could establish the importance of monitoring the antioxidant enzymatic profile of an athlete to know the status of training conditioning, fatigue limit, etc.

The presently studied summary data of MDA, SOD, GSH, and GPx indicates that endurance team-games such as football and hockey have any game specific references in terms of antioxidant variables, which might be due to the nature of energy requirement for the game and the high demand of recovery with a higher level of endurance capacity with a high burst of intense energy for short running sprints [17, 23, 25]. However, a single high-intensity exercise and/or even a long duration moderate-high intensity training of endurance team-games such as football and hockey were observed to induce oxidative stress via altering antioxidant biomarker enzymes and can create redox imbalance [1, 14, 17]. The present study can help to monitor the overreaching/overtraining condition of athletes by observing the resting data compared with well-defined reference intervals of antioxidant biomarkers (i.e., MDA, SOD, GSH, and GPx), which can finally lead to ROS induced damage to muscle and create exercise-induced fatigue and might limit sports performance.

This is one of the pioneer studies to access the RI of antioxidant biomarker variables in a sports/athletic population of the Indian subcontinent/origin. The study results will not only help to set guidelines to the athletes and coaches, but also maintain the balance between increasing training load and oxidative stress conditioning within the physiologic fatigue limit to reach the optimal performance. The major limitation of the present study was the moderate sample size (n = 190), as a bigger sample size will facilitate a more accurate standardization of the RI values in any given population. Another limitation of the study is the ethnicity of the study sample, i.e. the south-east Asian part. Total training volume in terms of % HR_{max} was not recorded and thus it is considered as a limitation of the study. The diet of the players during the study period was not thoroughly evaluated. So, the exact nutritional pattern and availability of daily ingested antioxidant levels could not be presented in the study and this is another major limitation of this investigation. All the players were considered homogeneous in nature in terms of their diet and socio-economic condition, since all of them were residing in the campus hostel and were having same diet throughout the day.

Conclusions

The present study concluded the RI range for antioxidant variables, i.e., MDA (24.55-35.58 µmoles/100 ml serum), SOD (0.06-0.13 U/min/mg protein), GSH (43.27-51.86 mg/100 ml serum) and GPx (9.07-14.12 µmol/min/mg protein) with precise limits. Both the games, football and hockey, did statistically differ in terms of resting antioxidant status and oxidative stress condition. An altered antioxidant enzymatic condition is an indirect prediction for training intensities and/or overtraining, which can be monitored with the help of reference values. Further, there is a close correlation of antioxidant variables with performance variables, i.e., endurance capacity, anaerobic power and explosive strength measure and thus the reference value will help to monitor the performance indirectly. Thus, the present study will help the athletes and coaches directly to avoid overreaching or overtraining and to maintain/ maximize their performance within the physiologic fatigue limit. The study will also help to clarify the misinterpretation of antioxidant biomarker variables during any competitive training phase of endurance team-game. Lastly, the study will help to standardize and enrich the population data set of reference value, which can be used for future researches.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

1. Azizbeigi K, Stannard SR, Atashak S, Haghighi MM. Antioxidant enzymes and oxidative stress adaptation to exercise training: comparison of endurance, resistance and concurrent training in untrained males. J Exerc Sci Fit. 2014;12:1-6. https://doi.org/10.1016/j.jesf.2013.12.001
2. Brancaccio P, Maffulli N, Buonauro R, Limongelli FM. Serum enzyme monitoring in sports medicine. Clin Sports Med. 2008;27(1):1-18. https://doi/org/10.1016/j.csm.2007.09.005
3. CLSI. Defining, establishing, and verifying reference intervals in the clinical laboratory: approved guideline. 3rd ed. CLSI Document C28-A3, Wayne, PA: Clinical and Laboratory Standards Institute; 2008.
4. de Araujo GG, Papoti M, dos Reis IGM, de Mello MAR, Gobatto CA. Short- and long-term effects of high-intensity interval training on hormones, metabolites, antioxidant system, glycogen concentration and aerobic performance adaptations in rats. Front Physiol. 2016;7:505. https://doi.org/10.3389/fphys.2016.00505
5. Dean M, Nemeskéri V, Gyore I, Harbula I, Malomsoki J, Pucsok J. Antioxidant status of interval-trained athletes in various sports. Int J Sports Med. 2006;27(2):112-116. https://doi.org/10.1055/s-2005-865634
6. Devrim-Lanpir A, Bilgic P, Kocahan T, Deliceoglu G, Rosemann T, Knechtle B. Total dietary antioxidant intake including polyphenol content: is it capable of fight against increased oxidants within the body of ultra-endurance athletes? Nutrients. 2020;12:1877. https://doi.org/10.3390/nu12061877
7. Gravina L, Ruiz F, Diaz E, Lekue JA, Badiola A, Irazusta J, et al. Influence of nutrient intake on antioxidant capacity, muscle damage and white blood cell count in female soccer players. J Int Society Sports Nutri. 2012;9:1-32. https://doi.org/10.1186/1550-2783-9-32
8. Horowitz GL, Altaie S, Boyd JC, Ceriotti F, Garg U, Horn P, et al. Defining, establishing, and verifying reference intervals in the clinical laboratory; approved guideline. 3rd ed. EP28-A3. Wayne, PA: Clinical & Laboratory Standards Institute. 2010;28:34–59.
9. Jamurtas AZ, Fatouras IG, Deli CK, Georgakouli K, Poulios A, Draganidis D, et al. The effects of acute low--volume HIIT and aerobic exercise on leukocyte count and redox status. J Sports Sci Med. 2018;17:501-508.
10. Jones G, Barker A. Reference interval. Clin Biochem Rev. 2008;29(Suppl 1):S93-S97.
11. Kuyumcu F, Aycan A. Evaluation of oxidative stress levels and antioxidant enzyme activities in burst fractures. Med Sci Monit. 2018;24:225-234. https://doi.org/10.12659/MSM. 908312
12. Mahmutyazicioglu J, Nash J, Cleves A, Nokes L. Is it necessary to adjust current creatine kinase reference ranges in professional footballers? BMJ Open Sport Exerc Med. 2018;4(1):e000282. https://doi.org/10.1136/bmjsem- 2017-000282
13. Metin G, Atukeren P, Alturfan AA, Gülyasar T, Kaya M, Gumustas MK. Lipid peroxidation, erythrocyte superoxide-dismutase activity and trace metals in young male footballers. Yonsei Med J. 2003;44(6):979-986. https://doi.org/10.3349/ymj.2003.44.6.979
14. Miyazaki H, Oh-ishi S, Ookawara T, Kizaki T, Toshinai K, Ha S, et al. Strenuous endurance training in humans reduce oxidative stress following exhausting exercise. Eur J Appl Physiol. 2001;84:1-6.
15. NCCLS. How to define and determine reference intervals in the clinical laboratory: approved guideline. 2nd ed. Clinical and Laboratory Standards Institute; 2000.
16. Nunes LAS, Lazarim FL, Brenzikofer R, Macedo DV. Applicability of the reference interval and reference change value of hematological and biochemical biomarkers to sport science. In: An International perspective on topics in sports medicine and sports injury; 2012. https://doi.org/10.5772/27971

17. Sarkar S, Debnath M, Das M, Bandyopadhyay A, Dey SK, Datta G. Effect of high intensity interval training on antioxidant status, inflammatory response and muscle damage indices in endurance team male players. Apunts Sports Med. 2021;56:1-11. https://doi.org/10.1016/j.apunsm.2021.100352
18. Sarkar S, Dey SK, Datta G, Bandyopadhyay A. Reference interval of muscle damage indices and cortisol in young athletes of various sports discipline. Int J Phys Educ Fit Sports. 2022;11(2):35-44. https://doi.org/10.34256/ijpefs2225
19. Sawka MN, Convertino VA, Eichner ER, Schneider SM, Young AJ. Blood volume: importance and adaptations to exercise training, environmental stresses, and trauma/sickness. Med Sci Sports Exerc. 2000;32(2):332-348. https://doi.org/10.1097/00005768-200002000-00012
20. Solberg HE. A guide to IFCC recommendations on reference values. J Int Fed Clin Chem. 1993;5(4):162-165.
21. de Sousa CV, Sales MM, Rosa TS, Lewis JE, Andrade RV, Simões HG. The antioxidant effect of exercise: a systematic review and meta-analysis. Sports Med. 2017;47:277--293. https://doi.org/10.1007/s40279-016-0566-1
22. Srividhya S, Majumdar P, Subramanian A. Reference interval for enzyme lactate dehydrogenase in male and female athletes. Int J Sci Res. 2017;6(1):394-398.
23. Ugras AF. Effect of high intensity interval training on elite athlete’s antioxidant status. Sci Sports. 2013;28:253-259. https://doi.org/10.1016/j.scispo.2012.04.009
24. Varamenti E, Tod D, Pullinger SA. Redox homeostasis and inflammation responses to training in adolescent athletes: a systematic review and meta-analysis. Sports Med Open. 2020;6:34. https://doi.org/10.1186/s40798-020-00262-x
25. Webb R, Hughes MG, Thomas AW, Morris K. The ability of exercise-associated oxidative stress to trigger redox sensitive signaling responses. Antioxidants. 2017;6(3):1--21. https://doi.org/10.3390/antiox6030063

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Table 1. Descriptive statistics and comparative analysis of maximal oxygen uptake (VO_2max in ml/kg·min^{-1}) between genotypes of the I/D *UCP2* gene polymorphism

UCP2			DD					ID					II		
Sex	*N*	$\bar{x}$	*SD*	*Min*	*Max*	*N*	$\bar{x}$	*SD*	*Min*	*Max*	*N*	$\bar{x}$	*SD*	*Min*	*Max*
F	42	45.65	*6.14*	32.30	59.00	36	45.66	*7.18*	30.60	59.80	7	45.07	*7.60*	35.00	54.80
M	72	54.01[a]	*6.20*	40.30	79.00	70	55.60	*7.32*	42.30	76.80	12	59.07[a]	*9.04*	49.70	74.90

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