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REVIEW

An update on the implication of physical activity on semen quality: a systematic review and meta-analysis

Jone Ibañez-Perez[1,2,3] · Borja Santos-Zorrozua[1] · Elixabet Lopez-Lopez[1,3] · Roberto Matorras[2,3] · Africa Garcia-Orad[1,3]

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Abstract

Purpose The aim of this study was to clarify whether physical activity may be associated with semen quality, considering the different types of sports, their intensity, and the semen parameters studied in the literature.

Methods Eligible studies included those that evaluated the impact of physical activity in semen parameters in human population. Outcomes evaluated included the following seminal quality parameters: volume, concentration, total sperm count, progressive motility, total motility, total motile sperm count, morphology, and motile sperm concentration.

Results We identified 32 manuscripts that analyzed this effect. Among them, 20 articles examined the role of general physical activity and 17 analyzed this relationship among specific sports. Although most results point to a lack of major effects of physical activity on semen quality, recreational physical activity could have a positive effect on semen concentration or progressive motility. On the contrary, elite physical activity could be detrimental for some semen parameters, such as progressive motility. Regarding specific sports, a negative effect of cycling on semen concentration is suggested.

Conclusions In conclusion, recreational physical activity seems to be of benefit for men with infertility issues. However, elite physical activity could have a detrimental effect on semen quality, which should be taken into consideration.

Keywords Physical activity · Sport · Infertility · Semen · Seminal quality parameter

Introduction

Infertility is an ongoing problem in developed countries. It has been described that over 10.1% of men and 12.5% of women of reproductive age will have infertility problems [1]. However, the causes of the increased prevalence of infertility are difficult to establish, regarding that many different lifestyles and environmental factors could have a role [2–4].

According to the recommendations of the World Health Organization (WHO), regular physical activity (PA) of moderate intensity, such as walking, cycling, or doing sports, is beneficial for health, reducing the risk of different diseases [5]. However, PA has been suggested to negatively impact reproduction. Actually, it is well documented that, in female athletes, excess or high-intensity PA is associated with alterations in the menstrual cycle that can lead to amenorrhea and, hence, produce infertility [6–8].

On the other hand, infertility in men has increased in the last years paired to a decrease in semen quality [9]. In this context, the impact of PA in semen quality has been analyzed in different studies. However, the contradictory results obtained have made it difficult to obtain convincing conclusions.

Some of these studies have focused on general PA and can be classified in three different groups based on the reported results: those that found a detrimental effect of PA on sperm [10, 11]; those that described a positive effect of PA on semen quality [12, 13], and those that did not find any association [14, 15]. Studies focused on specific sports, such as cycling or running, have obtained equally contradictory results [16–19], while the number of studies performed for other types of sports, such as tennis [19], triathlon [11, 16], or water polo [11], are too limited to

✉ Africa Garcia-Orad
africa.garciaorad@ehu.eus

[1] Department of Genetics, Physical Anthropology and Animal Physiology, Faculty of Medicine and Nursing, University of the Basque Country (UPV/EHU), Barrio Sarriena s/n, 48940 Leioa, Spain

[2] Human Reproduction Unit, Cruces University Hospital, Plaza Cruces s/n, 48903 Barakaldo, Spain

[3] BioCruces Health Research Institute, Plaza Cruces s/n, 48903 Barakaldo, Spain

draw conclusions. Differences in results could be due to different factors, including the type of sport analyzed, the way PA has been categorized, or the different seminal quality parameters studied.

Therefore, to clarify if PA may affect semen quality, we have performed a systematic review considering the different types of sports, PA intensity, and the seminal quality parameters studied, and performed meta-analyses whenever it was possible.

Material and methods

Search strategy

A systematic search was performed in PubMed database to identify studies that analyzed the association between PA and semen quality. We used the keywords and subject terms "(Physical activity OR exercise) AND (Semen quality OR seminal parameters OR Semen)" without any restriction according to publication date. The last update of this search was performed on October 10, 2017. Literature search was performed in accordance with PRISMA and MOOSE guidelines [20, 21].

Inclusion and exclusion criteria

Articles were included if they were independent original studies and evaluated the impact of PA in different seminal parameters in human population. Studies were excluded if they analyzed non-human or female populations, considered other factors related with infertility, performed molecular analysis, or were focused on other diseases. Case reports, reviews, author comments, abstracts, or articles not published in English were not included.

Data extraction

Eligible articles were reviewed independently by two authors (JI and BS). Disagreements were resolved by consensus. From each selected study, the following information was extracted: publication date, type of study (observational/interventionist), sample size, study population (healthy/infertile), analyses performed, World Health Organization (WHO) criteria used, and statistical results obtained in the analysis of the different seminal quality parameters (volume, concentration, total sperm count, progressive motility, total motility, total motile sperm count, morphology, and motile sperm concentration).

Level of physical activity

To classify the included articles, we defined different categories according to the type of sport, intensity, and frequency of PA reported.

General physical activity

1. Recreational moderate intensity physical activity:
   - This category refers to activities that take moderate physical effort and make the subject breathe somewhat harder than normal.
   - METs equivalents: 20–40 METs-h/week.
2. Recreational high-intensity physical activity:
   - This category refers to activities that take hard physical effort and make the subject breathe much harder than normal.
   - METs equivalents: 40–80 METs-h/week.
3. Elite physical activity:
   - This category refers to exhaustive endurance exercise including systematic resistance and power training.
   - Elite physical activity includes competitive sports or that performed by professional athletes.
   - METs equivalents: > 80 METs-h/week.

Specific sports

Specific exercise that can be differentiated from the rest of PA and other sports.

Control group category

- Sedentary activity
- No PA

Statistical analysis

The effect sizes of PA on the different seminal parameters were estimated by the mean difference (MD), as all of them were measured in the same scale, using Review Manager 5 [22], when the authors provided enough information in text, tables, or graphics. The overall pooled effect size (MD) and corresponding 95% confidence interval were estimated using the inverse of variance method, with random effects model. The random effects model assumes different underlying effects, considering both within- and between-study variations, offering an advantage, as it accommodates diversity between studies and provides

a more conservative estimate of the assessed effect. The heterogeneity was estimated using the I^2 statistic, which is independent of the number of studies in the meta-analysis. The I^2 statistic describes the percentage of total variation across studies due to between-studies heterogeneity rather than chance. A higher I^2 value denotes a greater degree of heterogeneity (0–25% no heterogeneity, 25–50% moderate heterogeneity, 50–75% large heterogeneity, and 75–100% extreme heterogeneity). Sensitivity analysis leaving out one study at the time was also performed when possible to identify outlying studies. To assess the publication bias in the meta-analysis, funnel plot and Egger's test were performed [23]. Statistical analyses were performed with R software version 3.4.3 [24], using the meta package [25]. In all cases and $\alpha = 0.05$ was set as significance level.

Results

Search results

A total of 242 articles were discovered following the search parameters. After abstract analysis, we identified 32 manuscripts that met the inclusion criteria to investigate the effect of PA in semen quality, of them, six where included in the meta-analysis (Fig. 1). After full-text revision, we classified the studies into two categories according to the type of exercise analyzed. In the first category, we included 20 studies that examined the implication of general PA in semen quality [10–13, 15–17, 19, 26–37]. The second category enclosed 17 studies that analyzed the relationship between specific sports and semen quality [11, 16–19, 29, 38–48]. Some of the articles analyzed both general PA and some specific sports, and were included in both categories.

Effect of general physical activity on seminal quality parameters

We found 20 articles in the literature focused on the study of general PA and its implication in different parameters measuring semen quality [10–13, 15–17, 19, 26–37]. We performed a detailed analysis of the studies and found contradictory results among them.

We considered that those contradictions could be due in part to differences among the measured seminal quality parameters or to lack of homogeneity in the type of PA considered. To address those differences, we separated the studies in this review in three groups based on the intensity

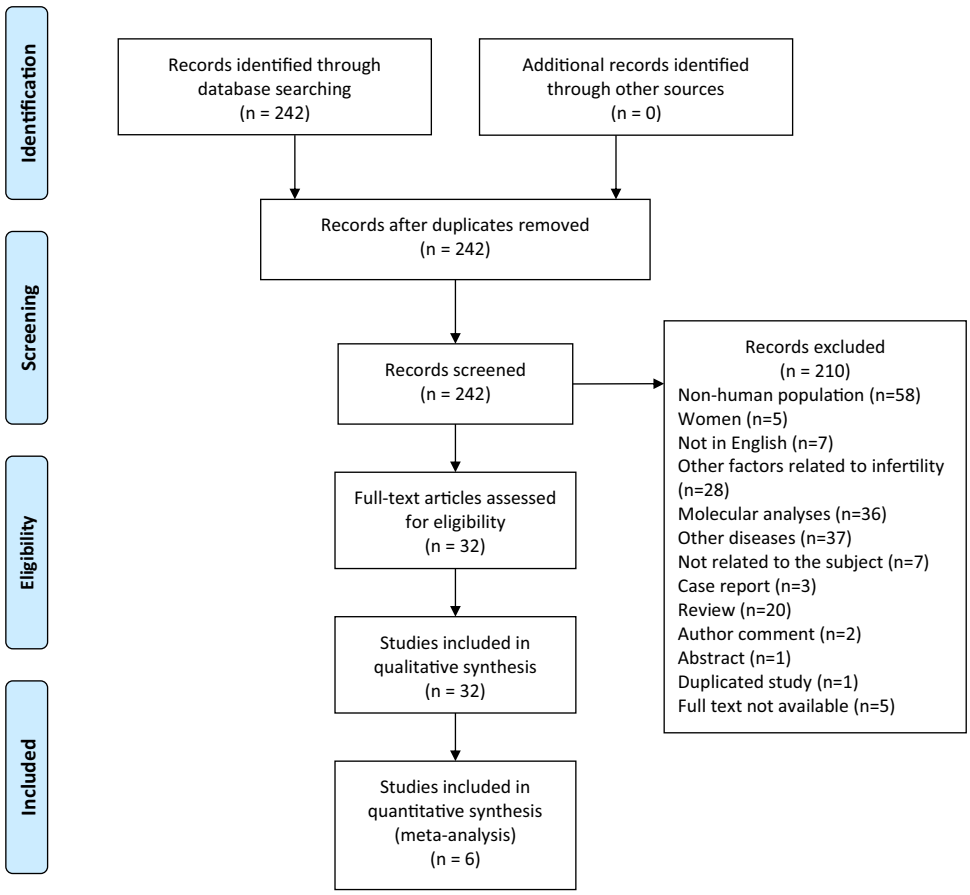

Fig. 1 Flowchart of the search strategy for study selection

Table 1 Summary of the studies that analyzed the effect of recreational moderate intensity physical activity (RMIPA) on semen quality including statistical significance and effect sizes

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Morphology (%)	Motile sperm concentration (10^6/ml)
Oldereid et al. [26]	Obs.	312 Infertile	Regular PA (%) distributed throughout normal, borderline and pathological groups for each parameter		NS	NS		NS			NS	
Wise et al. [17]	Obs.	2261 Infertile	Moderate PA (20–39 METs-hours/week); vs. control group (no regular exercise)	1999	NS	NS			NS	NS	NS	
Vaamonde et al.[28]	Obs.	31 Healthy	Physically active (> 6 h/week and $VO_{2max} \geq 40$ (ml/min/kg) vs. sedentary (0 h/week and $VO_{2max} < 40$ (ml/min/kg)	1999	NS	NS		+ 4.87 (1.49, 8.24)			+ 1.14 (0.12, 2.16)	
Hajizadeh Maleki et al. [29]	Obs.	161 Healthy	Recreationally active (8–15 h/week; VO_{2max} ~ 47–53 ml/min/kg) vs. sedentary group	2010	+ 2.1 (1.79, 2.41)	− 12.3 (− 19.23, − 5.37)	+ 43.2 (21.47, 64.93)		+ 26.0 (19.54, 32.46)		+ 7.3 (4.24, 10.36)	
Jurewicz et al. [30]	Obs.	344 Infertile	Leisure time activity (≥ 24 METs-hours/week) vs. no activity	1999	NS	(+)*			NS		NS	
			Leisure time activity (< 24 METs-hours/week) vs. No activity		NS	(+)*			NS		NS	
Mínguez-Alarcón et al. [14]	Obs.	215 Healthy	PA in METs-hours/week [moderate (Q1(0)–Q4(33.8)] vs. reference group Q1(0)	2010	NS	NS	NS		NS		NS	
			PA in hours/week [moderate (Q1(0)–Q4(7.5)] vs. reference group Q1 (0)		NS	NS	NS		NS		NS	

Table 1 (continued)

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Morphology (%)	Motile sperm concentration (10^6/ml)
Parn et al. [32]	Obs.	57 Infertile	Tertils of accumulation of activity T2 (moderate) vs T1 (low)	2010	NS	+ 36.32 (13.19, 59.45)	NS		NS	+ 27.56 (10.46, 44.66)		+ 93.76 (8.62, 178.90)
Priskorn et al.[33]	Obs.	1210 Healthy	Self PA assessment (good vs. poor)	2010	NS	+ 14.0 (6.01, 21.99)	+ 43.0 (16.32, 69.68)	NS			NS	
Hajizadeh Maleki and Tartibian [36]	Inter.	386 Infertile	24 weeks of moderate exercise: fist 12 weeks 25–30 min/day, 3–4 days/week at 45–55% VO_{2max}; last 12 weeks 40–45 min/day; 4–6 days/week at 56–69% VO_{2max} vs. non-exercise group	2010	NS	(+)*	(+)*	(+)*			(+)*	
Hajizadeh Maleki et al. [35]	Inter.	261 Healthy	24 weeks of exercise: moderate intensity continuous training vs. non-exercise	2010	NS	+ 5.45 (1.92, 8.98)	+ 36.36 (18.33, 53.39)	+ 3.27 (− 2.07, 10.75)			+ 2.22 (0.57, 3.87)	
Lalinde-Acevedo et al. [37]	Obs.	32 Healthy	Physically active group (8–48 MET) vs. sedentary group (< 3 MET)	2010	NS	NS	NS	+ 10.15 (1.89, 18.41)	+ 8.98 (2.63, 15.33)		NS	
Hajizadeh Maleki and Tartibian. [34]	Inter.	521 Infertile	24 week of exercise training: combined aerobic and resistance exercise training vs. non-exercise group	2010	NS	(+)*	(+)*	(+)*			(+)*	

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

Inter. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

*Not enough data available to quantify the differences between groups

of the activity performed: recreational moderate intensity physical activity (RMIPA) (Table 1) [17, 26, 28–37], recreational high-intensity physical activity (RHIPA) (Table 2) [12, 13, 17, 19, 31, 35], and Elite physical activity (EPA) (Table 3) [10, 11, 15, 16, 27, 29]. In addition, we analyzed the effect of both RMIPA and RHIPA in infertile men [12, 17, 19, 26, 30, 32, 34, 36]. In each group, we extracted the data of eight different seminal quality parameters (volume, concentration, total sperm count, progressive motility, total motility, total motile sperm count, morphology, and motile sperm concentration).

Recreational moderate intensity physical activity (RMIPA)

A total of 12 articles recorded fourteen analyses comparing RMIPA with lack of activity (Table 1) [17, 26, 28–37]. In those studies, eight different seminal quality parameters were analyzed (volume, concentration, total sperm count, progressive motility, total motility, total motile sperm count, morphology, and motile sperm concentration). Volume was considered in all of the 14 analyses [17, 26, 28–37], 13 of which did not provide any significant association [17, 26, 28, 30–37], suggesting a lack of correlation between RMIPA and semen volume. Similar results were obtained when total motility was studied. In this case, six out of eight analyses reported no significant association [17, 30–32], with a positive effect in the other two analyses [29, 37] (26% and 9% increase, respectively). Therefore, RMIPA does not seem to have a major effect on these two parameters. A controversy between a positive effect and lack of influence was observed for sperm morphology, 8 out of 13 analyses reporting no association with PA [17, 26, 30, 31, 33, 37]. On the other hand, a tendency towards a positive correlation was observed for other three parameters. In this line, when total sperm count and progressive motility were considered, a positive correlation was found in five out of nine [29, 33–36] and five out of seven [28, 34–37] analyses performed, with reported increases of around 30–40% and 8–20%, respectively. Regarding semen concentration, 7 comparisons out of the 14 that analyzed this parameter found a positive effect of RMIPA [30, 32–36]. By contrast, a rare negative association has been reported in an only study regarding semen concentration [29], which has not been replicated in the other 13 analyses including this parameter. Finally, the number of studies analyzing, total motile sperm count, and motile sperm concentration is too limited to draw any valid conclusions.

Recreational high-intensity physical activity (RHIPA)

The results obtained for RMIPA were similar to those reported for RHIPA. Six studies including nine analyses evaluated the effect of RHIPA on seminal quality parameters [12, 13, 17, 19, 31, 35] (Table 2). In those studies, seven different seminal quality parameters were analyzed (volume, concentration, total sperm count, progressive motility, total motility, total motile sperm count, and morphology). Volume and total motility were not found affected by RHIPA in any of the studies, in agreement with the tendency observed for RMIPA. The remaining seminal quality parameters considered in at least two studies (concentration, total sperm count, progressive motility, and morphology) showed either positive or no significant associations with RHIPA. No negative effects were reported.

Moderate- or high-intensity PA in infertile men

Interestingly, when we focused only on the articles that studied the implication of either RMIPA or RHIPA in parameters measuring semen quality in men from infertile couples [12, 17, 19, 26, 30, 32, 34, 36], the tendency was to support a positive association between recreational PA and concentration [12, 19, 30, 32, 34, 36], total sperm count [12, 34, 36], and progressive motility [12, 34, 36]. Although a minority of studies reported a lack of association [17, 19, 26, 32], it can be noted that none of the studies reported a negative association.

The lack of available data in a substantial amount of the studies did not allow the performance of an unbiased meta-analysis to further analyze the effect of recreational PA on semen parameters.

Elite physical activity

Only six studies analyzed the effect of exhaustive PA on six seminal quality parameters (volume, concentration, total sperm count, progressive motility, total motility, and morphology) in comparison with sedentary or recreational activity (Table 3) [10, 11, 15, 16, 27, 29]. In contrast to what was observed for recreational activity, some of the seminal quality parameters have been detrimentally associated with EPA. To further investigate these associations, we performed a meta-analysis for each seminal parameter (Fig. 2).

Regarding semen volume, one study out of six [10] observed a negative effect of EPA on semen volume, as opposed to the lack of association in the remaining studies. The data of 333 participants provided by the six studies [10, 11, 15, 16, 27, 29] were included in the meta-analysis and we found no statistically significant association between semen volume and EPA, even though a little tendency to a negative effect could be observed. The heterogeneity analysis showed moderate heterogeneity among studies (Fig. 2).

Contradictory results were found regarding semen concentration among the six studies performed [10, 11, 15, 16, 27, 29], negative, null or positive effects of EPA being reported. The six studies, providing data from 333

Table 2 Summary of the studies that analyzed the effect of recreational high intensity physical activity (RHIPA) on semen quality including statistical significance and effect sizes

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Wise et al. [17]	Obs.	2261 Infertile	Vigorous PA (≥40 METs-hours/week) Control group (no regular exercise)	1999	NS	NS			NS	NS	NS	
Gaskins et al. [19]	Obs.	231 Infertile	Correlation of moderate to vigorous PA in hours/week Analysis between quartiles Q4 (10.7) vs, Q1 (0.3)	2010		+ 18.5 (1.19, 35.81)	NS	NS			NS	
			Correlation of PA in METs-hours/week) Analysis between quartiles Q4 (79.3) vs. Q1 (5.4)			NS	NS	NS			NS	
Mínguez-Alarcón et al. [14]	Obs.	215 Healthy	PA in METs-hours/week (vigorous (Q1(0)–Q4(39)); vs. reference group Q1	2010	NS	NS	NS		NS		NS	
			PA in hours/weeks vigorous Q1(0)–Q4(6,5) vs. reference group Q1		NS	NS	NS		NS		NS	

Table 2 (continued)

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Gaskins et al. [13]	Obs.	189 Healthy	Moderate to vigorous PA in hours/week Analysis between quartiles Q4 (15–50) vs. Q1(0–4.5)	1999	NS	+ 24.12 (6.2, 42.04)	+ 53.85 (− 15.62, 123.32)	NS	NS		NS	
Hajizadeh Maleki et al. [35]	Inter.	261 Healthy	24 weeks of exercise: high intensity interval training: first 12 weeks 10 × 1 min intervals/3 times week; last 12 weeks 15 × 1 min intervals/3 times week vs. non-exercise	2010	NS	NS	NS	+ 2.12 (− 4.41, 8.65)			+ 0.55 (− 1.27, 2.37)	
			24 weeks of exercise: high intensity continuous training protocol: first 12 weeks 40–50 min/3 times week; last 12 weeks 50–60 min/3 times week vs. non-exercise		NS	NS	NS	+ 1.01 (− 5.04, 7.06)			+ 1.1 (− 0.64, 2.86)	

Table 2 (continued)

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Maleki and Tartibian. [12]	Inter.	433 Infertile	24 weeks of exercise protocol: first 12 weeks high-intensity 40–50 min/3 times week; Last 12 weeks 50–60 min/3 times week Non-exercise group	2010	NS	(+)*	(+)*	(+)*			(+)*	

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

Inter. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

*Not enough data available to quantify the differences between groups

Table 3 Summary of the studies that analyzed the effect of elite physical activity (EPA) on semen quality including statistical significance and effect sizes

References	Type of study	*N*	Analysis performed	WHO criterion (years)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Lucía et al. [16]	Obs.	18 Healthy	Triathletes (Preco.17 ± 4 h/week; Com. 19 ± 4 h/week; Rest 0 h/week) vs. controls (0 h/week)	1992	NS	NS			NS		NS	
Di Luigi et al. [27]	Obs.	120 Healthy	Competitive athletes (> 8 h/week) vs. non-athletes (< 3 h/week)	1992	NS	NS		NS	NS		NS	
Vaamonde et al. [10]	Inter.	16 Healthy	2 weeks of exhaustive endurance training group (maximal exercise until exhaustion 4 days/week) vs. Control group	1992	− 1.13 (− 1.77, − 0.48)	− 18.56 (− 31.15, − 5.98)	− 96.46 (− 139.35, − 49.57)				− 5.41 (− 7.33, − 3.49)	
Vaamonde et al. [11]	Inter.	45 Healthy	Triathletes (20 h/week) vs. physically active (3 h/week)	1999	NS	− 12.8 (− 26.30, 0.70)	− 50.5 (− 96.2, − 4.08)	NS			− 10.5 (− 11.76, − 9.24)	
Hajizadeh Maleki et al. [29]	Obs.	161 Healthy	Elite athletes (high intensity activity > 8 h/week; VO_{2max} 58–67 ml/min/kg) vs. sedentary group		NS	+ 13.5 (5.99, 21.01)	+ 21.8 (2.78, 4.82)		− 17.3 (− 23.18,− 11.42)		− 7.9 (− 11.04, − 4.76)	
Jozkow et al. [15]	Obs.	177 Healthy	Physical activity in METs-min/week Analysis between quartiles Q4 (> 7038) vs. Q1 (< 2133)	2010	NS	NS	NS	NS			NS	

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

Inter. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

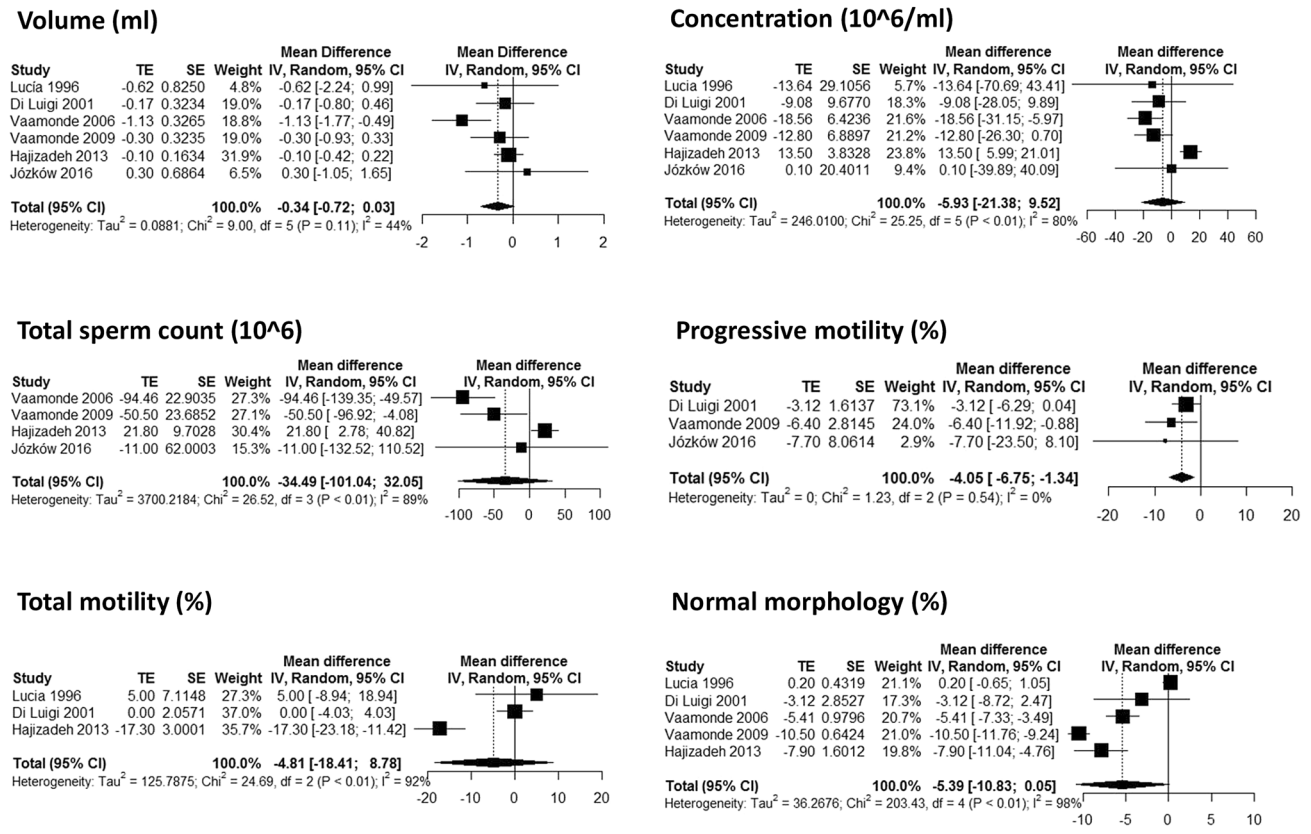

Fig. 2 Results of meta-analysis of the effect of EPA on seminal parameters. The squares and horizontal lines represent the mean difference and confidence interval for each individual study. The diamonds represent the pooled results. The vertical dotted lines represent the mean differences of the meta-analyses. TE: mean difference for each study; SE: Standard Error; IV: Inverse of Variance method

participants, were included in the meta-analysis providing non-significant results. The heterogeneity analysis showed extreme heterogeneity among studies ($I^2 = 80\%$; p value = 0.0001), the study by Hajizadeh et al. (2013) [29] being identified as an outlier.

Contradictory results were also found for total sperm count [10, 11, 15, 29]. The pooled MD obtained from the meta-analysis of the data regarding 255 individuals provided by the four studies included was not statistically significant. Just as in the study of semen concentration, an extreme heterogeneity among studies was observed ($I^2 = 89\%$; p value < 0.0001), the study by Hajizadeh et al. (2013) [29] being identified as an outlier.

On the other hand, no association was found between EPA and progressive motility in the three studies performed [11, 15, 27]. Interestingly, when the data from 190 individuals included in the three studies were meta-analyzed, a statistically significant negative effect of EPA was observed with an overall MD = − 4.05% (95% CI: − 6.75%, − 1.34%; p value = 0.0034) (Fig. 2).

When total sperm motility was considered, one study out of three [29] observed a negative effect of EPA on total motility, while the other two studies did not find any association. The meta-analysis performed including data from 187 participants obtained from the three studies [16, 27, 29] did not find a significant association between total sperm motility and EPA (Fig. 2). The heterogeneity analysis showed extreme heterogeneity among studies ($I^2 = 92\%$; p value < 0.0001), the study by Hajizadeh et al. [29], which was the only one reporting a negative association, was identified as an outlier.

Finally, morphology was negatively associated with EPA in three out of six studies [10, 11, 29]. Five of the studies provided enough data, from a total of 234 participants, to be included in the meta-analysis [10, 11, 16, 27, 29]. A tendency to a negative effect of EPA on morphology could be observed, although the results were not statistically significant (MD = − 5.39, 95% CI: − 10.83%, 0.05%; p value = 0.0521) (Fig. 2). The heterogeneity analysis showed extreme heterogeneity among studies ($I^2 = 98\%$; p value < 0.0001), although in this case, no clear outlier was identified.

Effect of specific sports on seminal quality parameters

We found 17 articles in the literature focused on the study of specific sports and their implication in seminal quality [11, 16–19, 38–48]. We grouped these studies according to the type of sport analyzed and we made an exhaustive analysis of the data. The following groups were considered: cycling [16, 17, 19, 43–45] (Table 4), running [16–19, 39–42, 46, 47] (Table 5), and other sports [11, 16, 17, 19, 38, 40, 48] (Table 6). In this third group, different sports were grouped because of the limited number of studies found for each sport: aerobics [19], fighting sports [48], outdoor sports [19], soccer [38], squash [19], swimming [19], tennis [19], triathlon [11, 16], water polo [11], and weightlifting [17, 19, 40].

Cycling

Regarding cycling, only six studies were carried out [16, 17, 19, 43–45] (Table 4). So far, four of them with less than 25 subjects [16, 43–45]. It should be noted that the two studies with larger sample size [17, 19] detected a moderate decrease in sperm concentration associated with cycling, which was also reported in two of the studies with more limited sample size [44, 45].

Running

With respect to running, ten studies have been carried out [16–19, 39–42, 46, 47] (Table 5). So far, 6 of them with less than 30 subjects [16, 39, 40, 42, 46, 47]. Considering this fact, the statistical power of the studies is questionable. If we take into account only the other four studies [17–19, 41], which included 150 or more individuals, we come across non-significant or contradictory results. For instance, semen concentration was positively associated [41], negatively correlated [18], and no associated with running in different studies [17, 19]. Considering all this results, it is not feasible to establish an association between running and semen quality.

Other sports

Concerning other sports, we found few studies carried out for each type of sport (Table 6). Considering the heterogeneity observed, both in the type of sport and in the intensity in which these sports have been practiced, it is not viable to draw final conclusions. However, we can note that in the majority of cases, the preliminary results available do not point to any significant effect of those sports on semen quality.

Discussion

In this systematic review, we performed a detailed analysis of the current literature on the effect of PA on seminal quality. Separating the studies by the type of PA and seminal quality parameters analyzed allowed a more detailed picture of the role of PA.

It must be noted that there was a remarkable heterogeneity regarding studies. The criteria used for measuring the PA and the different categories were not homogeneous: while some studies were observational and authors used METs in their classification [17, 30, 37], other authors used the maximum rate of oxygen consumption (V_{O2} max) [28, 29] and other studies were interventionists [10, 35, 36]. Moreover, moderate- and high-intensity PA were not defined in the same way by the different authors and elite PA includes very different scenarios. On the other hand, the sperm parameters considered differ among studies. In addition, the study population differed from healthy men [28, 31, 33, 35] to men from infertile couples [12, 17, 19, 26, 30, 32, 34, 36].

Our approach showed that RMIPA could have a positive effect on semen quality. In fact, most studies point to a positive effect of RMIPA on some specific parameters, such as semen concentration [30, 32–36], total sperm count [29, 33–36], and progressive motility [28, 34–37]. Similar results were found for RHIPA, with seminal quality parameters, such as semen concentration, total sperm count, progressive motility, and morphology, reported to be either positively or no significantly correlated with RHIPA [12, 13, 17, 19, 31, 35]. Therefore, the current literature suggests that both RMIPA and RHIPA could be beneficial for some seminal quality parameters. On the other hand, the reported experience is reassuring concerning the lack of an adverse effect of RMIPA and RHIPA on sperm quality, since only in one out of 112 data reported in the 15 publications a poor outcome was reported, while the remaining were either no null ($n=73$) or positive ($n=38$). However, we could not perform a meta-analysis to further support these qualitative results due to the biased lack of available data in several studies for each parameter.

Interestingly, when we focused only on the articles that studied the implication of recreational PA in semen quality in men from infertile couples [12, 17, 19, 26, 30, 32, 34, 36], the tendency was to support a positive association between recreational PA and specific parameters such as concentration [12, 19, 30, 32, 34, 36], total sperm count [12, 34, 36] and progressive motility [12, 34, 36]. Therefore, these results suggest that recreational PA might have some

Table 4 Summary of the studies that analyzed the effect of cycling in seminal quality parameters including statistical significance and effect sizes

References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Lucía et al. (1996) [16]	Obs	21 Healthy	Competition (884.4 + 44,7 km/week; 26 + 2 h/week) vs. sedentary controls	1992	NS	NS			− 18.34 (− 33.31, − 3.37)		NS	
Gebreegziabher et al. [43]	Obs	20 Healthy	Cyclist (4–6 session/week; 1–2 h/session) vs. controls (0–3 sessions/week; 0 h/session)	1999	NS	NS	NS		NS		− 21.0 (− 33.8, − 8.20)	
Wise et al. [17]	Obs	2261 Infertile	Cyclist (≤ 2 h/week;3–4 h/week; ≥ 5 h/week) vs. controls (0 h/week)	1999	NS	(−)* (> 5 h)			NS		NS	(−)* (> 5 h)
Gaskins et al. [19]	Obs	231 Infertile	Cyclist (> 1.5 h/week) vs. controls (0 h/week)	2010		− 18.64 (− 36.59, − 0.69)	NS	NS			NS	
Maleki et al. [14]	Int	24 Healthy	First 8 week of training (371 + 41,6 km/week; 12 + 4 h/week) Second 8 week (659 + 47, 8 km/week; 16 + 3 h/week) vs. control (Baseline)	2010	− 1.2 (− 1.58, − 0.82)	− 22.3 (− 29.08, − 15.52)	− 140.0 (− 156.37, − 123.64)		− 32.0 (− 42.34, − 21.66)		− 6.6 (− 8.68, − 4.52)	
Hajizadeh and Tartibian [45]	Int	24 Healthy	First 8 week of training (371 + 41,6 km/week; 12 + 4 h/week) Second 8 week (659 + 47,8 km/week; 16 + 3 h/week) vs. control (baseline)	2010	− 1.2 (− 1.58, − 0.82)	− 22.3 (− 29.08, − 15.52)	− 140.0 (− 156.37, − 123.64)		− 32.0 (− 42.34, − 21.66)		− 6.6 (− 8.68, − 4.52)	

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

Inter. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

*Not enough data available to quantify the differences between groups

Table 5 Summary of the studies that analyzed the effect of running in seminal quality parameters including statistical significance and effect sizes

Reference	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Bagatell et al. [39]	Obs.	23 Healthy	Marathon runners (VO_{2max} 63.9 ± 1.2 ml/kg*min) vs. controls (VO_{2max} 47.2 ± 3.5 ml/kg*min)			NS	NS		NS			
Arce et al. [40]	Obs	20 Healthy	Endurance trained runners (109.2 ± 4.8 km/week; 9.7 ± 1.0 h/week) vs. controls (0 km/week; 0 h/week)		NS	− 98.0 (− 152.35, − 43.65)	NS	− 17.9 (− 28.24, − 7.56)		NS	NS	
De Souza et al. [47]	Obs	30 Healthy	High mileage runners (VO_{2max} 66.6 ± 1.8 ml/kg*min; 108.0 ± 4.5 km/week; 9.7 ± 1.0 h/week) vs. controls (VO_{2max} 42.7 ± 1.7 ml/kg*min)	1987	+ 1.6 (0.21, 2.99)	NS	NS	− 18.4 (− 28.05, − 8.75)		− 90.2 (− 180.02, − 0.38)	NS	
			Moderate mileage runners (VO_2 Max 59.8 ± 1.7 ml/kg*min; 54.2 ± 3.7 km/week; 3.2 ± 1.2 h/week) vs. controls (VO_{2max} 42.7 ± 1.7 ml/kg*min)	1987		NS	NS	− 9.9 (− 19.90, 0.10)		NS	NS	
Jensen et al. [41]	Obs.	151 Healthy	High training runners (84.9 ± 20.8 km/week) vs. reference group: low training runners (28.7 ± 18.5 km/week)		NS	(+)*			NS		(+)*	

Table 5 (continued)

Reference	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
					Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Lucía et al. [16]	Obs	19 Healthy	Runners (competition 94.2 ± 27.1 h/week; 8 ± 4 h/week.) vs. controls (0 h/week)	1992		NS	NS	.	NS		NS	
Hall et al. [46]	Inter.	16 Healthy	Runners (VO_2 max 58.71 ± 7.01 ml/kg*min) vs. controls (0 h/week)		NS	NS	NS		NS		NS	
Di Luigi et al. [42]	Obs	16 Healthy	Runners (VO_{2max} 63.5 ± 2.8 ml/kg*min) vs. controls (VO_{2max} 44.1 ± 3.2 ml/kg*min)	1992		NS		NS		NS	NS	
Safarinejad et al. [18]	Inter.	286 Healthy	High intensity exercise group(~ 80%VO_{2max}) vs. reference group: moderate intensity exercise (~ 60% VO_{2max})	1992	NS	− 21.4 (− 22.38, − 20.42)	− 55.0 (− 61.65, − 48.35)		− 13.6 (− 14.43, − 12.77)		NS	
Wise et al. [17]	Obs.	2261 Infertile	Runners (≥ 5 h/week) vs. controls (0 h/week)	1999	NS	NS			NS		NS	NS
Gaskins et al. [19]	Obs.	231 Infertile	Runners (> 2.5 h/week) vs. controls (0 h/week)	2010		NS	NS					

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

V volume, *C* concentration, *TSC* total sperm count, *PM* progressive motility, *M* total motility, *NM* non progressive motility, *IM* immobile, *MSC* total motile sperm count, *MP* morphology, *MSCon* motile sperm concentration, *Inter*. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

*Not enough data available to quantify the differences between groups

Table 6 Summary of the studies that analyzed the effect of other sports in seminal quality parameters including statistical significance and effect sizes

Sport	References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
						Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Aerobics	Gaskins et al. [19]	Obs.	231 Infertile	Aerobics (0.1–5 h/week) vs. sedentary controls (0 h/week)	2010		NS	NS					
Fighting sports	Tartibian et al. [48]	Obs	108 Healthy	Fighters (O_{2max} 62.3 ± 5.9 ml/min/kg) vs. physically active (VO_{2max} 50.1 ± 4.4 ml/min/kg)	1992	− 2.2 (− 2.48, − 1.92)	+ 25.8 (23.25, 28.35)	− 42.3 (− 50.81, − 33.79)		− 43.3 (− 48.36, − 38.24)		− 15.2 (− 17.24, − 13.16)	
Outdoor activities	Gaskins et al. [19]	Obs.	231 Infertile	Out activities (0.1–5 h/week) vs. sedentary controls (0 h/week)	2010		NS	NS					
Soccer	Celani et al. [38]	Obs.	15 Infertile	Soccer players (2 times/week = 2 h of endurance running and 1 h of intense running) for three month; a weekly 90 min football match) vs. sedentary controls		NS	NS		− 14.1 (− 19.93, 8.27)				
Squash	Gaskins et al. [19]	Obs.	231 Infertile	Squash players (0.1–8.5 h/week) vs. sedentary controls (0 h/week)	2010		NS	NS					
Swimming	Gaskins et al. [19]	Obs.	231 Infertile	Swimmers (0.1–8.5 h/week) vs. sedentary controls (0 h/week)	2010		NS	NS					
Tennis	Gaskins et al. [19]	Obs.	231 Infertile	Tennis players (0.1–2.5 h/week) vs. sedentary controls (0 h/week)	2010		NS	NS					

Table 6 (continued)

Sport	References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
						Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Triathlon	Lucía et al. [16]	Obs.	18 Healthy	Triathletes (Preco.17 ± 4 h/week; Com. 19 ± 4 h/week; rest 0 h/week) vs. controls (0 h/week)	1992	NS	NS			NS		NS	
	Vaamonde et al. [11]	Obs.	32 Healthy	Triathletes (VO_{2max} 64.0 ± 5.1 ml/min/kg; 9.9 ± 1.8 session/week; 122.6 ± 62.7 min/session) vs. physically active (VO_{2max} 45.2 ± 4.2 ml/min/kg; 3.3 ± 0.4 session/week; 60 ± 0 min/session)	1999	NS	− 12.8 (− 26.30, 0.70)	− 50.5 (− 96.2,− 4,08)	NS			− 10.5 (− 11.76, − 9.24)	
Water polo	Vaamonde et al. [11]	Obs.	30 Healthy	Water polo players (VO_{2max} 54.2 ± 4.9 ml/min/kg; 5 ± 0 session/week; 90 ± 0 min/session) vs. physically active (VO_{2max} 45.2 ± 4.2 ml/min/kg; 3.3 ± 0.4 session/week; 60 ± 0 min/session)	1999	NS	NS	NS	NS			− 5.5 (− 7.18, − 3.82)	

Table 6 (continued)

Sport	References	Type of study	*N*	Analysis performed	WHO criterion (year)	Seminal parameters							
						Volume (ml)	Concentration (10^6/ml)	Total sperm count (10^6)	Progressive motility (%)	Total motility (%)	Motile sperm count (10^6)	Normal morphology (%)	Motile sperm concentration (10^6/ml)
Weightlifting	Arce et al. [40]	Obs	18 Healthy	Weightlifters (9.9 ± 1.2 h/week) vs. sedentary controls (0 h/week)		NS	NS	NS	NS			NS	
	Wise et al. [17]	Obs.	2261 Infertile	Weightlifters (≥5 h/week) vs. sedentary controls (0 h/week)	1999	NS	NS		NS		NS	NS	
	Gaskins et al. [19]	Obs	231 Infertile	Weightlifters (≥2 h/week) vs. sedentary controls (0 h/week)	2010		+ 11.25 (− 5.65, 28.15)	NS					

Effect sizes are presented as mean difference (95% confidence interval) and estimated from the information provided in text, tables or graphics in the included study

V volume, *C* concentration, *TSC* total sperm count, *PM* progressive motility, *M* total motility, *NM* non progressive motility, *IM* immobile, *MSC* total motile sperm count, *MP* morphology, *MSCon* motile sperm concentration, *Inter*. interventionist study, *Obs*. observational study, *NS* no statistically significant association with PA as reflected in the included study, *(+)* positive association with PA as reflected in the included study, *(−)* negative association with PA as reflected in the included study

*Not enough data available to quantify the differences between groups

beneficial impact that could be of interest to improve some seminal quality parameters in male patients with infertility problems.

On the contrary, EPA has been repeatedly correlated with a decline in some semen quality parameters in the studies published in the literature, including volume [10], concentration [10, 11], total motility [29], and morphology [10, 11, 29], pointing to EPA as possibly detrimental for semen quality. The meta-analyses performed pointed to progressive motility as the parameter that presented the greatest detrimental effect of EPA among semen parameter reaching statistical significance, while volume and morphology were very close to the significance limit. It is important to note that progressive motility was not significantly associated with EPA in any of the individual studies, but the detrimental effect was revealed once the three studies were combined [11, 15, 27].

Nevertheless, there are still some limitations in the meta-analyses performed. First, the number of studies retrieved from the literature was quite small, and as none of these six studies, reported measures of all of the seminal parameters considered; in some meta-analyses, the number of pooled studies decreased. Second, the heterogeneity found in some meta-analyses was very high (concentration, total sperm count, total sperm motility, and morphology). We explored the sources of this heterogeneity by an influential analysis and found that except for morphology, the heterogeneity was due to the study made by Hajizadeh et al. [29]. Other possible sources of heterogeneity could have been the different way that included studies determine the intensity of physical activity (using METS [15] or hours/week [11]), and the sport practiced by the participants in these studies.

Regarding the effect of specific sports on seminal quality parameters, the literature is in general too limited and the results too contradictory to establish reliable associations with semen quality. In the specific case of cycling, the only two studies performed with larger sample size observed an association with decreased sperm concentration [17, 19]. Considering these results, cycling might negatively affect sperm concentration. However, these very preliminary results should be confirmed.

To summarize, concerning recreational PA, both RMIPA and RHIPA, seem to be associated with better semen quality, suggesting that the performance of recreational activity (20–80 METs-h/week) could improve sperm parameters in infertile men with poor sperm quality,. However, more studies, especially interventional ones, are needed to confirm our proposals. It should be remembered that it is difficult to separate EPA from other associated parameters (intake, body weight, non-smoking, and illicit drugs). However, it can be concluded from our study that EPA should not be recommended to infertile men to improve sperm quality. We should probably recommend avoiding EPA among men with poor sperm quality, although more studies are needed to confirm this recommendation. Regarding specific sports, cycling has been associated with a decrease in some seminal quality parameters such as concentration, but, in general, the number of studies is too limited to draw final conclusions. Therefore, we could conclude that recreational PA seems to be associated with a better sperm quality; however, when PA is practiced until exhaustion, it can negatively affect some seminal quality parameters.

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Author contributions AGO and RM contributed to the conception and design of the study. JIP and BSZ acquired and analyzed the data. JIP, ELL, and AGO interpreted the results and drafted the article. AGO acquired and administrated the funding. All authors have read, reviewed critically and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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