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Physical activity is not related to semen quality in young healthy men

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Abstract

Objective—To study the relation of physical activity with semen quality among healthy young men from Spain.

Design—Cross-sectional study.

Setting—University and college campuses of Murcia Region, Spain.

Patients—Healthy young men with untested fertility (n=215).

Intervention—A physical examination, blood and semen samples, and completion of a questionnaire.

Main outcomes measure—Semen quality parameters.

Results—Physical activity was not related to semen quality parameters. The adjusted percentage differences (95% confidence interval) in semen parameters comparing men in the top quartile of

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AMTC and JM planned the study. JM acquired the data. LMA and JC analyzed and interpreted the data. LMA, JEC and AJG drafted the manuscript.

moderate to vigorous physical activity (9.5h/wk) to men in the bottom quartile (3h/wk) were 4.3% (−30.2, 38.9) for total sperm count, 7.2% (−30.6, 45.1) for sperm concentration, −2.42% (−6.53, 1.69) for sperm motility, and 12.6% (−12.0, 37.2) for sperm morphology.

Conclusion—In contrast to previous research among athletes, these data suggest that physical activity is not deleterious to testicular function, as captured by semen quality parameters in this population of healthy young men in Spain.

Keywords

Semen quality parameters; physical activity; young healthy men; Spain

INTRODUCTION

Infertility affects approximately one in six couples who try to get pregnant (1) and male factor is identified in as many as 58% of the couples evaluated for infertility (2). Two meta-analyses have documented a drastic decrease in semen quality in Western populations during the 20th century (3, 4), and multiple single center studies have found a continuation of this trend into the first decade of the 21st century (5–8). While the downward trend in semen quality is likely multifactorial, with a variety of lifestyle factors exerting negative (9–11) and positive (12–13) influences on spermatogenesis, the most commonly endorsed hypothesis is that this trend reflects increased population-wide exposure to endocrine-disrupting chemicals (EDC) with estrogenic or anti-androgenic activity (3, 14–15). Nevertheless, other factors coinciding with the decline may also explain this trend. For example, the obesity epidemic (16–18), increased paternal age (19), and secular changes in diet quality (20), are equally likely potential explanations for this downward trend. However, other alternative hypotheses like increased sedentary activity and lower physical activity (21–22), have, until recently, received little attention (23–24).

Physical activity is a particularly attractive target for potential lifestyle modification among men trying to conceive. On one hand, there is strong evidence of multiple health benefits of in adults. All types and intensities of physical activity reduce rates of all-cause mortality, metabolic syndrome, high blood pressure and coronary heart disease, and can improve bone health and cognitive function, for example (25–28). However, the literature on the relation of physical activity with semen quality and other markers of testicular function presents contradictory results (21–22, 29–37). Many studies have reported that physical activity may be deleterious for sperm production (29–31, 36). However, the majority of studies in this field have focused almost exclusively on the effect of high-intensity training among elite athletes in a relatively narrow range of activities (29–37) or men presenting at fertility clinics (21), raising concerns on the generalizability of the existing literature. Specifically, high-intensity physical activity characteristic of professional athletes may have very different physiological effects on testicular function than activity levels that most men in the general population are able to achieve. Moreover, men presenting to fertility centers tend to differ systematically from men in the general population in a wide variety of socio-economic factors raising the possibility that associations identified in the setting of a fertility clinic may not be directly translatable to other men. To further address this question, we examined

the relation of moderate physical activity with semen quality among healthy young men from Spain.

MATERIAL AND METHODS

Study population

The Murcia Young Men's Study (MYMS) was a cross-sectional study carried out between October 2010 and November 2011 in the Murcia Region of Spain. Healthy male university students, age 18 to 23 years.. Recruitment flyers were posted at university campuses. Two hundred and forty students contacted study staff. Of these, 17 subjects were ineligible. Of the remaining 223 eligible men, 215 (96%) agreed to participate and completed a study visit. During the study visit, men underwent a physical examination, and provided a semen sample. All of them also completed questionnaires concerning demographics, medical and reproductive history, medication use (antibiotics, antidepressants and hormones) and smoking habits. Diet was assessed using a validated questionnaire (38–40). Men received a €50 gift card for their participation. Written informed consent was obtained from all subjects. The Research Ethics Committee of the University of Murcia approved this study (no. 495/2010, approved 14 May 2010).

Physical examination

Body weight and height were measured using a digital scale (Tanita SC 330-S, London, UK). Body mass index (BMI) was calculated as weight in kilograms divided by squared height in meters. Presence of varicocele was evaluated and recorded as no varicocele, only detected during Valsalva procedure, palpable or visible. The presence of other scrotal abnormalities was also recorded. Testicular volume was measured using a Prader orchidometer (Andrology Australia, Clayton, Victoria, Australia).

Physical activity assessment

Participants were asked to report the number of hours they spent in a normal week over the past 3 months engaged in vigorous, moderate or light exercise. While this questionnaire has not been validated among Spanish men, similar physical activity questionnaires have been validated in other populations (41). Total activity was calculated as the sum of vigorous, moderate and light activity. Moderate-to-vigorous activity was calculated as the sum of those categories, respectively. We also calculated the total metabolic equivalents (METs) and moderate-to-vigorous METs. Mild (<3 METs), moderate (3–6 METS) and vigorous (>6 METs) activities were given an average MET level of 2, 4.5 and 6, respectively, to calculate the total METs per person (42). Total METs was calculated as the sum of vigorous, moderate and light METs. Also moderate-to-vigorous METs was calculated as the sum of those METs categories, respectively. For example, a man who spent 7 hrs/wk in vigorous, 2 hrs/wk in moderate and 4 hrs/wk in light activities would accumulate 13 hrs/wk of total physical activity, 9 hrs/wk of moderate-to-vigorous activity, 42MET-h/wk of vigorous activity (7h at 6 METs), 9 MET-h/wk of moderate activities 8 MET-h/wk of light activity, 51 MET-h/wk of moderate-to-vigorous physical activity and 59 MET-h/wk, of total activity.

Semen collection and analysis

Men were asked to abstain from ejaculation for at least 48 hours before sample collection. However, if subjects had not abstained for that period of time, they were not excluded (n=30). Abstinence time was recorded as the time between current and previous ejaculation as reported by the study subject. Men collected semen samples by masturbation at the clinic. Ejaculate volumes were estimated by specimen weight, assuming a semen density of 1.0 g/mL. Sperm concentration was evaluated by haemocytometer (Improved Neubauer; Hauser Scientific Inc., Horsham, PA, USA). Spermatozoa were classified as motile [progressive and non-progressive (PR + NPR)] according to the WHO criteria (43). Sperm morphology was assessed using strict criteria (44). Total sperm count (volume $\times$ sperm concentration) was also calculated. All semen analyses were performed by the same individual. An external quality control on semen analysis was carried out in collaboration with the University of Copenhagen's Department of Growth and Reproduction.

Statistical analyses

Semen volume, sperm concentration, total sperm count, and percentage of morphologically normal sperm showed non-normal distributions and were transformed using the natural log (ln) before analysis. Men were divided into quartiles of physical activity. Men with the lowest physical activity category were considered as the reference group. Linear regression was used to examine the association of physical activity with semen quality parameters while adjusting for potential confounders. Tests for linear trend were performed using the median values of physical activity in each quartile as a continuous variable and semen parameters as the response variable. Confounding was assessed using a hybrid method that combines previous knowledge using directed acyclic graphs (DAGs) (45) and a statistical method on change in point estimates in which the potential covariate was not retained in final models, if it resulted in a change in the β -coefficient of $< 10\%$. The variables considered as potential confounders and examined using DAGs, included factors previously related to semen quality in this and other studies, and factors associated with physical activity and semen parameters in this study, regardless of whether they had been previously described as predictors of semen quality. Final models included terms for BMI (kg/m²), smoking (current smoker vs. not current smoker), presence of varicocele (yes vs. no), TV watching (hours/week), caffeine intake (mg/day), and intakes of micronutrients previously related to semen quality in this population (vitamin C, β -cryptoxanthin, lycopene and β -carotene) (46). Abstinence time (hours) and time to start semen analysis (minutes; for sperm motility only) were also included in the final models in keeping with the literature despite the fact that they did not behave as confounders. Because these are strong predictors of the semen quality indicators, their inclusion in the models results in gains in efficiency for the estimation of the association of interest by reducing the amount of unexplained random variability in the model. We used analysis of covariance (ANCOVA) to calculate adjusted semen parameters for each quartile by relevant covariates. Multivariate ANCOVA models were created with continuous semen parameters as dependent variables, and physical activity and TV watching categories and covariates as independent variables. We considered that an association was present when we found statistically significant linear trend across quartiles. All tests were two-tailed and the level of statistical significance was set at 0.05.

Statistical analyses were performed with the statistical package IBM SPSS 19.0 (IBM Corporation, Armonk, New York, USA).

RESULTS

Participants had a median (interquartile range (IQR)) age of 20.4 (19.6, 21.4) years and were predominantly Caucasian (97.2%). All men considered themselves in good health and 31.5% were current smokers. The median (IQR) BMI was 23.7 (21.7, 25.5) kg/m².

Approximately 2% of men had a history of cryptorchidism and 15% had a varicocele in the left testis. The median (IQR) abstinence time was 71 hours (59, 92). The median (IQR) values for semen analysis parameters were 42.9×10⁶/mL (21.9,72.2×10⁶/mL) for sperm concentration; 121.5 ×10⁶ (65.4,212.7) for total sperm count; and 57.2% (50.7,63.8%) for sperm motility (PR + NPR). On average, men in our study engaged in five hours per week of moderate-to-vigorous activity per week. The men on the top quartile of METs had shorter abstinence time and consumed more antioxidant vitamins compared to the men on the first quartile (Table 1). These relations were not statistically significant, though.

Our study suggests an inverse relation between total physical activity time and sperm morphology (P, trend = 0.07) (Figure 1). Relative to men in the lowest quartile of total physical activity, the adjusted percent difference (95% Confidence Interval (CI)) of morphologically normal sperm for men in the 2nd, 3rd and 4th quartiles were 2 (−21 to 26), −7 (−33 to 19) and −20 (−45 to 5) percent, respectively. However, total physical activity was unrelated to other semen quality parameters (Figure 1). A similar pattern was observed when physical activity was expressed as metabolic equivalents (data not shown).

There were no associations between physical activity and semen quality parameters when this relation was examined separately for light, moderate, vigorous or the sum of moderate and vigorous activities. There were no discrepancies when physical activity was either expressed as time per week (Table 2) or as MET-hours/wk (Table 3).

In addition, effect modification by BMI (<25kg/m² and ≥25kg/m²) and TV watching (dichotomized as above and below the median, 20 h) was tested using cross product-terms in the final models, to determine whether the relationships between physical activity and semen quality parameters were modified by them. There was no evidence of significant heterogeneity on the relation between physical activity and sperm concentration, motility, morphology, or total sperm count (p, interaction>0.05), by levels of BMI and TV watching, even when physical activity was expressed like total METs.

DISCUSSION

We found no evidence of a detrimental effect of physical activity on semen quality parameters among young healthy men in Spain. These data suggest that the literature on physical activity and markers of spermatogenesis among athletes may overstate potential harms of physical activity on testicular function and may not be generalizable to the general population.

Most of the existing literature evaluating the relation between physical activity and semen quality has focused on endurance athletes or men presenting to fertility clinics (21, 29–31, 34, 36–39, 47–49), and suggests that bicycling may negatively influence sperm concentration (22), and that high-intensity professional sports could impair sperm motility (49) and morphology (34). The findings among endurance athletes, which are based on extreme levels of physical activity, could be explained by a negative energy balance during competition as well as mechanical trauma caused by compression of scrotum on bicycle saddle and/or to a prolonged increase in core scrotal temperature related to exercise itself or wearing of constrictive clothing among cyclists. In contrast to elite athletes, physical activity in the general population tends to be more modest, requiring less energy expenditure and thus rarely resulting in prolonged negative energy balance (50–51). Given the scarcity of data on the relation between physical activity and semen quality parameters among non-athletes, it is important that this relation is further evaluated.

Our results do not support the hypothesis that physical activity is detrimental for testicular function. In agreement with our results, some studies have found no association between physical activity and semen parameters, even among endurance athletes (48). Hall and co-workers found no statistically significant associations between runners and control subjects in reproductive hormones or cortisol, sperm count, motility and morphology. Similarly, in the largest study to date among 2261 men of couples attending a fertility clinic, there was no association between total physical activity and sperm parameters (21). It is important, however, to consider our findings in light of a recent report of a positive association between physical activity and semen quality among young men in the United States (22). In this study, moderate-to-vigorous physical activity was significantly related to higher sperm concentration and total sperm count (P , trends = 0.003 and 0.04, respectively). The American and the current study were simultaneously designed as part of an international consortium and thus shared multiple characteristics including target population, physical activity assessment tools, physical examination procedures, and quality control procedures for semen analyses. A possible explanation for the apparently different results may be the difference in the distribution of physical activity between participants in these two studies. The median time spent on moderate to vigorous physical activities was 3.25 hours/wk higher in the American study (8.25 h/wk) compared to ours (5 h/wk). For example, the median time spent in moderate-to-vigorous physical activity for men in the top quartile in our study was 12 h/week, compared to 20 h/week in the American one. Therefore, given that the study design were quite similar, the higher levels of physical activity among participants in the American study are more likely to be a plausible explanation for the divergent findings. In addition, although neither of the two studies had information about the type of physical activity that men were engaging in, these activities could be different between the two countries. Since diverse physical activities may affect spermatogenesis differently among athletes (37), there is no reason to think otherwise among general population. Moreover, Safarinejad and coworkers showed that among men practicing the same type of physical activity, intensity of the activity mattered, as 10h/wk of high intensity running was related to worse semen quality parameters while 10h/wk of moderate intensity running was not (36).

Our study is not without limitations. First, the cross-sectional design severely limits our ability to infer causality. However, our study was restricted to young men who were

presumably unaware of status when filling out their fertility the baseline questionnaire. Thus, for all practical purposes, these men were blinded to the study outcomes minimizing the possibility that men had changed their physical activity in response to knowledge of fertility potential leading to reverse causation; a common concern in cross-sectional studies. Second, it is possible that the narrow age range limited our ability to detect associations of semen quality with lifestyle factors in general and physical activity in particular. However, we have previously reported associations with other lifestyle factors in this population and studies with similarly narrow age ranges have previously reported associations between physical activity and semen quality (22) suggesting that this may not be a serious concern. Third, only one sample of semen was obtained from each man. However, there appears to be limited advantages to using more than one semen sample in epidemiological studies (52–53). Fourth, as it is true for all observational studies, misclassification of physical activity is possible. However, similar physical activity questionnaires have been validated for use in epidemiologic studies (41) and the same questionnaire was used in a previous study that reported a positive association between physical activity and sperm concentration (19). An additional problem of the questionnaire used in this study is that it does not differentiate between specific activities which impeded an evaluation of whether specific activities may have different relations with semen quality as previous work suggests (21). Our questionnaire does not assess physical activity related to occupation or daily living either and it is therefore not possible to make any inferences regarding their potential role from these data. Last, data on reproductive hormone levels were unavailable and we were unable to evaluate their relation with physical activity. The strengths of our study include the use of a previously validated FFQ (38–40), and the comprehensive assessment of a wide range of potential confounders.

CONCLUSIONS

In summary, physical activity (<5hr/wk and 0–40hr/wk, median and range respectively) was not related to semen quality parameters in young healthy Spanish men. Our results are not consistent with the hypothesis that physical activity has a deleterious effect on testicular function and raises concerns regarding the generalizability of findings of studies examining the relation between physical activity and markers of testicular function among endurance athletes. Further evaluation of the relation of physical activity with semen quality and other markers of testicular function among non-athletes is needed to better characterize any effects physical activity may have on male reproductive function.

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Figure 1. Associations between quartiles of total activity and semen quality parameters
Mean and 95% confidence interval values are adjusted for BMI (kg/m^2), smoking (current smoker vs. not current smoker), ejaculation abstinence time (hours), presence of varicocele (yes vs. no), TV watching (hours/week), caffeine intake (mg/day), and other micronutrients resources (trans fatty acids, vitamin C, β -cryptoxantin, lycopene and β -carotene) (g/day). Models for sperm motility are additionally adjusted for time to start semen analysis (minutes). Tests for trend were conducted across quartiles using a variable with the median activity level in each quartile as a continuous variable in the linear regression models.

Table 1

Demographic characteristics across quartiles of total METs^a.

	Total cohort (n=215)	Q1 (n=54) (IQR=8.5–18.0)	Q2 (n=54) (IQR=23.50–30.13)	Q3 (n=56) (IQR=38.0–47.0)	Q4 (n=51) (IQR=63.0–107.0)	P Value^b
Age (years)	20.4 (19.6–21.4)	20.5 (19.6–21.3)	20.3 (19.3–21.6)	20.4 (19.7–21.4)	20.5 (19.6–21.4)	0.99
Caucasian, n (%)	210 (97.2)	52 (96.3)	54 (100)	56 (100)	51 (100)	0.32
BMI (kg/m ²)	23.7 (21.7–25.5)	23.5 (21.1–25.6)	23.6 (21.2–25.4)	23.3 (21.9–25.4)	24.6 (22.4–25.5)	0.54
Current smoker, n (%)	68 (31.5)	18 (33.3)	17 (31.5)	18 (32.1)	15 (29.4)	0.97
Abstinence time (h)	71.0 (59.0–92.0)	73.5 (61.8–94.0)	81.5 (64.0–94.5)	66.0 (50.3–88.5)	72.0 (51.0–88.0)	0.12
Variocoele, n (%)	33 (15.7)	5 (9.3)	9 (16.6)	7 (12.5)	12 (23.5)	0.38
History of cryptorchidism, n (%)	4 (1.9)	0 (0)	0 (0)	2 (3.6)	2 (3.9)	0.40
Trans fatty acids intake (g/day)	1.7 (1.2–2.2)	1.7 (1.3–2.4)	1.6 (1.2–2.0)	1.7 (1.1–2.2)	1.4 (1.1–2.1)	0.25
Vitamin C intake (mg/day)	111.4 (76.6–142.2)	100.7 (69.2–129.7)	118.8 (73.0–150.5)	109.8 (78.2–141.1)	124.3 (77.1–149.2)	0.23
Lycopene intake (mcg/day)	3938.7 (2446.2–5867.9)	3204.5 (2007.8–5398.1)	4747.7 (3172.1–6364.0)	4205.5 (2964.4–5969.2)	3470.6 (2357.7–5398.3)	0.02
B-carotene intake (mcg/day)	2435.5 (1493.0–4227.0)	1970.2 (1297.0–3414.2)	2910.5 (2022.3–4273.6)	2361.8 (1679.8–4353.8)	2365.5 (1288.3–4380.3)	0.07
Cryptoxanthine intake (mcg/day)	275.7 (157.4–403.6)	241.1 (131.8–327.5)	277.6 (168.2–419.5)	288.4 (140.2–428.0)	280.2 (164.7–422.6)	0.38
Caffeine intake (mg/day)	76.4 (24.7–159.0)	50.9 (28.9–133.5)	78.3 (19.9–174.8)	73.7 (19.1–113.6)	86.6 (25.4–173.2)	0.28
TV watching (h/week)	20.0 (14.0–41.0)	25.0 (14.0–36.5)	20.0 (14.0–41.0)	20.0 (14.0–35.0)	29.0 (20.0–44.0)	0.21

^aContinuous variables are shown as median and interquartile range (IQR) unless otherwise indicated.^bFor continuous variables, Kruskal-Wallis analyses of variance were used to test for associations across quartiles of activity. For categorical variables, χ^2 tests were used to test the associations between quartiles of activity.

Table 2

Multivariate adjusted^a associations of physical activity intensity and semen parameters (n=215).

Median (range) for each quartile (hours/week)		n	Motile Sperm		Morphologically Normal Sperm		Sperm Concentration		Total Sperm Count	
			%	95% CI	%	95% CI	(10 ⁶ /ml)	95% CI	(10 ⁶)	95% CI
Light activity										
Q1 0 (0)	48	56.87	53.89–59.85		8.62	7.20–10.33	38.24	29.02–50.45	110.28	85.54–142.02
Q2 2.0 (1.0–2.0)	53	56.40	53.45–53.36		9.63	8.01–11.58	43.60	33.18–57.28	107.34	83.18–138.38
Q3 3.0 (2.5–4.0)	35	57.49	53.94–61.03		8.45	6.81–10.48	37.49	26.95–52.14	136.05	100.18–184.75
Q4 8.0 (4.5–40.0)	79	56.92	54.49–59.35		8.41	7.26–9.75	33.78	27.09–42.14	102.31	83.35–125.71
P _{trend}		0.94			0.61		0.29		0.53	
Moderate activity										
Q1 0 (0–1.0)	61	57.45	54.79–60.12		9.03	7.65–10.65	35.77	27.85–45.97	101.19	80.32–127.48
Q2 2.0 (1.5–3.0)	73	55.28	52.85–57.71		8.64	7.44–10.02	40.29	32.07–50.65	120.30	97.51–148.56
Q3 4.0 (4.0–5.0)	39	57.00	53.68–60.31		9.47	7.71–11.62	39.45	28.90–53.84	101.90	76.70–135.37
Q4 7.5 (6.0–20.0)	42	58.71	55.42–62.00		7.93	6.51–9.55	34.36	25.48–46.34	115.35	87.53–152.17
P _{trend}		0.39			0.42		0.77		0.68	
Vigorous activity										
Q1 0 (0)	65	57.20	54.60–59.81		8.82	7.52–10.34	35.95	28.22–45.79	93.97	75.34–117.33
Q2 2.0 (1.0–2.0)	53	56.63	53.77–59.50		9.47	7.94–11.30	38.09	29.17–49.70	129.93	101.60–166.17
Q3 4.0 (3.0–4.0)	49	54.55	51.60–57.50		8.76	7.29–10.52	36.05	27.28–47.66	120.42	93.50–154.93
Q4 6.5 (4.5–20.0)	48	59.11	56.04–62.18		7.92	6.58–9.54	41.18	30.97–54.76	104.06	80.32–134.83
P _{trend}		0.62			0.34		0.55		0.59	
Mod-vig activity										
Q1 2.0 (0–3.0)	65	56.33	53.72–58.93		8.91	7.60–10.43	38.94	30.54–49.65	106.06	83.86–132.56
Q2 4.0 (3.5–5.0)	45	56.38	53.23–59.52		10.16	8.37–12.32	33.01	24.60–44.30	96.74	73.92–126.73
Q3 7.0 (6.0–9.0)	59	56.43	53.68–59.18		8.31	7.01–9.84	41.22	31.91–53.25	135.37	107.13–171.23
Q4 12.0 (9.5–40.0)	46	58.75	55.58–61.91		7.85	6.50–9.48	36.23	27.09–48.47	101.60	77.94–132.30
P _{trend}		0.26			0.14		0.99		0.78	

^a Adjusted for BMI (kg/m²), smoking (current smoker vs. not current smoker), ejaculation abstinence time (hours), presence of varicocele (yes vs. no), TV watching (hours/week), caffeine intake (mg/day), and other micronutrients resources (trans fatty acids, vitamin C, (β-cryptoxanthin, lycopene and (β-carotene) (g/day). Models for sperm motility are further adjusted for time to start semen analysis (minutes).

^b Significantly different to mean in the lowest quartile of intake at p<0.05.

Table 3

Multivariate adjusted^a associations of metabolic equivalents of physical activity and semen parameters (n=215).

Median (range) for each quartile (hours/week)	n	Motile Sperm		Morphologically Normal Sperm		Sperm Concentration		Total Sperm Count	
		%	95% CI	%	95% CI	(10 ⁶ /ml)	95% CI	(10 ⁶)	95% CI
Light mets									
Q1 0 (0–2.0)	65	56.91	54.33–59.49	9.09	7.77–10.62	39.85	31.37–50.65	114.55	91.93–142.74
Q2 4.0 (4.0–6.0)	54	56.90	54.08–59.72	8.52	7.15–10.16	36.53	28.13–47.47	103.33	80.72–132.16
Q3 10.0 (7.0–12.0)	42	56.03	52.76–59.30	9.12	7.47–11.12	42.31	31.22–53.34	123.10	93.13–162.88
Q4 20.0 (14.0–80.0)	52	57.49	54.53–60.44	8.27	6.91–9.90	32.92	25.18–43.03	102.51	79.84–131.63
P _{trend}		0.81		0.53		0.37		0.66	
Moderate mets									
Q1 0 (0–4.5)	61	57.45	54.79–60.12	9.03	7.65–10.65	35.77	27.85–45.97	101.19	80.32–127.49
Q2 9.0 (6.75–13.5)	73	55.28	52.85–57.71	8.64	7.44–10.02	40.29	32.07–50.65	120.30	97.51–148.56
Q3 18.0 (18.0–22.5)	39	57.00	53.68–60.31	9.47	7.71–11.62	39.45	28.90–53.84	101.90	76.71–135.37
Q4 33.8 (27.0–90.0)	42	58.70	55.42–61.99	7.93	6.51–9.65	34.36	25.48–46.34	115.35	87.53–152.17
P _{trend}		0.39		0.42		0.77		0.68	
Vigorous mets									
Q1 0 (0)	65	57.20	54.60–59.81	8.82	7.52–10.34	35.95	28.22–45.79	93.97	75.34–117.33
Q2 12.0 (6.0–12.0)	53	56.63	53.77–59.49	9.47	7.94–11.30	38.09	29.17–49.70	129.93	101.60–166.17
Q3 24.0 (18.0–24.0)	49	54.55	51.60–57.50	8.76	7.29–10.52	36.05	27.28–47.66	120.42	93.50–154.93
Q4 39.0 (27.0–120.0)	48	59.11	56.04–62.18	7.92	6.58–9.54	41.18	30.97–54.76	104.06	80.32–134.83
P _{trend}		0.62		0.34		0.55		0.59	
Mod-vig mets									
Q1 4.5 (0–13.5)	56	57.42	54.61–60.24	8.69	7.32–10.30	38.36	29.52–49.85	102.62	80.80–130.32
Q2 21.0 (15.0–27.0)	52	55.72	52.85–58.60	9.95	8.35–11.86	34.09	26.02–44.61	99.48	77.79–127.23
Q3 35.3 (28.5–45.0)	54	56.34	53.46–59.23	9.09	7.62–10.85	40.00	30.60–52.25	141.74	111.05–181.09
Q4 60.0 (46.5–210.0)	53	58.00	55.03–60.96	7.47	6.27–8.91	38.17	29.08–50.15	101.80	79.60–130.32
P _{trend}		0.68		0.14		0.83		0.78	

^a Adjusted for BMI (kg/m²), smoking (current smoker vs. not current smoker), ejaculation abstinence time (hours), presence of varicocele (yes vs. no), TV watching (hours/week), caffeine intake (mg/day), and other micronutrients resources (trans fatty acids, vitamin C, (β-cryptoxanthin, lycopene and (β-carotene) (g/day). Models for sperm motility are further adjusted for time to start semen analysis (minutes).

^b Significantly different to mean in the lowest quartile of intake at p<0.05.