Original Article

Awareness, attitudes, and eating behaviors of gym users in Saudi Arabia regarding red and processed meat

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ABSTRACT

Background: Consumption of red meat (RM) and processed meat (PM) is associated with the development of colorectal cancer (CRC). Gym users use RM and PM as supplements for their workouts. This puts them at risk of developing cancer.

Method: Self-administered questionnaires were used to evaluate the level of awareness, eating behaviors, and potential risks associated with specific foods among gym users in Saudi Arabia from November 2021 to August 2022. Demographic factors were also assessed, the questionnaire was distributed using online platforms including WhatsApp and Twitter.

Results: In our study, 41.2% (n=123) and 70.8% (n=211) of the participants rarely consumed RM and PM per week, with the highest consumption of less than 500 g per week 31.9% (n=95) for RM. Only 7.4% (n=22) exceeded 1000 g of weekly RM and PM consumption. Maleness, high protein intake (>200 g/day), supplementary protein intake, good income (>5000 SAR) and being a healthcare worker were associated with higher RM consumption. In contrast, being a dietitian or sports coach was associated with less PM (p=0.045) consumption. The overwhelming majority of subjects 81.2% (n=242) had never heard of nitrites and N-nitroso compounds; knowing about these compounds and their carcinogenic potential was associated with a lower RM consumption (p=0.033).

Conclusion: More educational campaigns on RM and PM are needed to address the lack of understanding of their associated risks, especially for male athletes and people with good socio-economic status.

Keywords: colorectal cancer, gym, processed meat, red meat

INTRODUCTION

Food intake is one of the most important environmental causes of cancer.[1] It is the strongest environmental risk factor for colorectal cancer CRC.[2] Approximately half of CRC cases can be prevented by diet, weight reduction, and routine exercise.[1] In October 2015, the International Agency for Research on Cancer (IARC) categorized red meat (RM) consumption as 'probably carcinogenic' (Group 2A) based on limited evidence and processed meat (PM) consumption as 'carcinogenic' to humans (Group 1) based on sufficient evidence.[1]

Red meat refers to beef, pork, lamb, and goat from domesticated animals, while PM refers to meat preserved through smoking, salting, curing, or the addition of other chemical preservatives.[1,3] Red meat and PM have also been associated with other types of cancer, such as pancreatic and prostate cancer.[1,4] According to the new World Cancer Research Fund/American Institute for Cancer Research

(WCRF/AICR) recommendation in 2018, red meat should be limited to no more than three portions per week. Three portions are equivalent to approximately 350–500 g (approximately 12–18 oz) cooked weight. Very little, if any, processed meat should be consumed.[5]

The pathogenesis of PM and RM-related cancers most likely involves nitrites and N-nitroso compounds (NOCs), heme iron (HI), heterocyclic amines (HCAs), and polycyclic aromatic hydrocarbons (PAHs). Red meat contains high levels of heme iron, which stimulates the endogenous formation of carcinogenic N-nitroso compounds that promote colorectal tumorigenesis.[1] HCAs and PAHs are produced when meat is cooked at high temperatures.[5] These chemicals have been linked to carcinogenesis.[1,6,7]

Despite the above risk, RM is one of the most important high-quality protein sources with high biological value that can fulfill the muscle metabolic requirements of athletes.[8] Athletes' needs are dependent on training status; however, a protein intake of 1.2–1.7 g per kg per day is sufficient for endurance and resistance-trained athletes.[9] However, surveys of athletes indicate that they commonly consume more than the aforementioned requirement.[9] An Italian study[10] performed in 2011 before the IARC classification that assessed the eating behaviors of gym users and focused on supplement use indicated that athletes who used protein supplements also had a higher intake of protein-rich food, with a particular preference for meat.[10] Therefore, gym users seem to be at a greater risk of exceeding the recommended intake based on the above studies[9-10] that appear to indicate a higher meat intake among them. Factors other than sports can potentially affect RM and PM consumption, such as sociodemographic variables, dietary behaviors, and knowledge of the potential risks of RM and PM consumption.[11-16] Existing literature highlights that social inequalities are important determinants of health.[13] A study also showed a positive association between high education and healthy dietary habits, indicating that healthy food (for example, fruit or vegetables) consumption was greater in the higher than in the lower education group; in contrast, less healthy food (for example, PM) consumption was greater in the lower than in the higher education group[12] Moreover, the consumption of RM-PM was higher in men.[15] Based on these studies, evaluating RM and PM intake among athletes and the sociodemographic factors that can potentially affect it seems important. In addition, it would be interesting to determine if athletes are aware of the risks associated with these foods and if knowledge about the risks associated with RM and PM can affect RM and PM intake. In 2014, a study conducted in Germany, Italy, Holland, and Belgium on knowledge of PM, showed that approximately half of the participants had never heard about nitrites being added to PM.[16]

In this study, we aimed to investigate the knowledge of RM and PM among gym users and their eating behaviors; to analyze whether sports, social and demographic characteristics, and nutritional factors could affect RM and PM consumption; and to assess whether less understanding of the possible risks associated with consuming RM and PM is related to higher consumption of these types of food.

METHODS

This cross-sectional study was conducted in all 13 regions of Saudi Arabia among adults aged 18 years and older from November 2021 to August 2022. Participants were consecutively included using social media platforms. Data were collected using a self-administered, anonymous online questionnaire. The questionnaire was translated into Arabic using forward and backward translations to confirm the maintenance of construct validity. The questionnaire was developed and modified after an intensive literature review[11-25] and expert consultation. The first section of the questionnaire focused on the sociodemographic characteristics of the participants, such as age, gender, residence, level of education, employment status, marital status, and CRC family history. The second part was developed to assess the type and duration of sport practiced. The third section assessed information about diet and supplement

intake. The fourth section assessed data on eating behaviors (for example, weekly food frequency and portion size), focusing on RM and PM intake. The last section focuses on knowledge and awareness of the potential risks associated with RM and PM ingestion. The questionnaire was distributed using various social media applications such as WhatsApp and Twitter.

Ethical approval: Shaqra University granted ethical approval from the Medical Research Ethics Committee (ERC) via ERC No. ERC_SU_20210045, dated 2/11/2021.

RESULTS

A total of 304 gym users were reached, and 300 participants agreed to participate in this study. Out of the 300 questionnaires collected, 298 were filled appropriately and used for the analyses. Most of the participants were from the central region 49.7% (n=148) where males counted for 69.3% (n=207). However, the greatest number of subjects 36.2% (n=108) were in the 18–24 age group. The major sport practiced that was most commonly reported by the athletes was resistance training 86.2% (n=257); for a duration of 2–5 years 27.9% (n=83), and 6–12 hours per week 37.2% (n=111). More than half of the study population 64.4% (n=192) stated that they were on a diet with the main goal being to stay healthy 32.9% (n=98) (Table-1).

Table 1: Descriptive analysis: socio-demographic, sports, and dietary information.

Variable	Percentage n (%)	Variable	Percentage n (%)
Gender	Males 207 (69.3%) Females 91 (30.5)	Sport duration	Less than 6 months 35 (11.7%) 6-12 months 44 (14.8%) 1-2 years 73 (24.5%) 2-5 years 83 (27.9%) More than 5 years 63 (21.1%)
Age	Less than 18, 14 (4.7%) 18-24, 108 (36.2%) 25-30, 104 (34.9%) 31-40, 53 (17.8%) 41-50, 18 (6%) More than 50, 1 (0.3%)	Hours per week at gym	3 hours and less 78 (26.2%) 3-6 hours 94 (31.5%) 6-12 hours 111 (37.2%) More than 12 hours 15 (5.0%)
Region	Central 148 (49.7%) Northern 17 (5.7%) Eastern 38 (12.8%) Western 79 (26.5%) Southern 16 (5.4%)	Being on diet	Yes 192 (64.4%) No 106 (35.6%)
Education	High school 50 (16.8%) College student 90 (30.2%) Bachelor degree 133 (44.6%) Higher degree 25 (8.4%)	Thinking that supplementary proteins are needed in the diet	Yes 59 (19.8%) No 239 (80.2%)
Marital status	Not married 221 (74.2%) Married 77 (25.8%)	Taking supplements	Yes 178 (59.7%) No 120 (40.3%)
Background	Sports field 28 (9.3%) Healthcare field 42 (14.1%) Others 228 (76.6%)	Consumption of fruit and vegetables <400g daily	Yes 253 (84.9%) No 45 (15.1%)
Sport practiced	Resistance training 257 (86.2%) Cardiorespiratory 30 (10.1%) Football 9 (3%) Others 2 (0.7%)	Proteins mostly consumed g/day	Less than 100g/d 43 (14.4%) 100-150g/d 115 (38.6%) 150-200g/d 77 (25.8%) More than 200g/d 13 (4.4%) Not counting 50 (16.8%)

In this study, the majority of the subjects rarely consumed RM weekly 41.2% (n=123), with the highest consumption of less than 500 g a week 31.9% (n=95). In addition, the largest number of subjects stated

that they rarely or never ate PM 70.8% (n=211), and only 7.4% (n=22) exceeded 1000 g of weekly RM and PM consumption. Approximately half of the study population 55.4% (n=165) rarely or never used barbecuing, broiling, or griddling meat as a cooking method, with 'well-cooked' being the most common degree of cooking used 69.1% (n=206) (Table 2).

Table 2: Descriptive analysis: Red and processed meat consumption.

Variable	Percentage n (%)
Consumption of fresh red meat per week	Once a week 55 (18.5%)
	Twice a week 60 (20.1%)
	More than twice 60 (20.1%)
	Rarely/never weekly 123 (41.2%)
Consumption of fresh red meat, grams per week	Less than 500g, 95 (31.9%)
	500-1000g, 77 (25.8%)
	More than 1000g, 22 (7.4%)
	Rarely/never weekly 104 (34.9%)
Frequency of barbecuing/broiling/griddling meat	Always 56 (18.8%)
	Most of the times 43 (14.4%)
	Half of the times 34 (11.4%)
	Rarely/never 165 (55.4%)
Degree of cooking most used	Rare 3 (1%)
	Undercooked 2 (0.7%)
	Medium 71 (23.8%)
	Well-cooked 206 (69.1%)
	Overcooked 16 (5.4%)
Consumption of processed meat per week	Once a week 29 (9.7%)
	Twice a week 24 (8.1%)
	More than twice 34 (11.4%)
	Rarely/never 211 (70.8%)
Consumption of processed meat, grams per week	Less than 500g, 42 (14.1%)
	500-1000g, 21 (7.0%)
	More than 1000g, 22 (7.4%)
	Rarely/never weekly 213 (71.4%)

Table 3: Descriptive analysis: Awareness about red and processed meat.

Variable	Percentage n (%)
Reading the nutrition label before buying red and processed meat	Always 116 (38.9%)
	Most of the time 54 (18.1%)
	half of the time 23 (7.7%)
	Rarely/ never 105 (35.3%)
Do you hear about nitrites and N-nitroso compounds (NOCs)?	Yes 56 (18.8%)
	No 242 (81.2%)
Do you know what is nitrites and N-nitroso compounds (NOCs)?	Yes 27 (9.1%)
	No 271 (90.9%)
Do you think that an excessive consumption of sodium and potassium nitrite/nitrate can be correlated to cancer development?	Yes 18 (6%)
	No 20 (6.7%)
	I don't know 260 (87.2%)

In this study population, the overwhelming majority of participants 81.2% (n=242) had never heard of nitrites and N-nitroso compounds; only 9.1% (n=27) knew what these compounds were, and only 6% (n=18) stated that there was a relationship between nitrites and N-nitroso compounds and cancer development. Only 35.3% (n= 105) of participants rarely or never read the nutrition label before buying meats (Table 3).

Table 4: Descriptive analysis: Relationships between fresh red meat consumption (grams per week) and other variables.

Variable	Percentage n (%)		P-value
Gender	**Males** • <500g: 67 (32.4%) • 500g-1000g: 67 (32.4%) • >1000g: 19 (9.2%) • Rarely weekly 43 (20.8%) • Never: 11 (5.3%)	**Females** • <500g: 28 (30.8%) • 500g-1000g: 10 (11.0%) • >1000g: 3 (3.3%) • Rarely weekly 47 (51.6%) • Never: 3 (3.3%)	0.000
Education	**High school degree** • <500g: 17 (34%) • 500g-1000g: 12 (24%) • >1000g: 2 (4%) • Rarely weekly 17 (34%) • Never: 2 (4.0%)	**Bachelor degree** • <500g: 45 (33.8%) • 500g-1000g: 37 (27.8%) • >1000g: 11 (8.3%) • Rarely weekly 34 (25.6%) • Never: 6 (4.5%)	0.363
	College student • <500g: 25 (27.8%) • 500g-1000g: 23 (25.6%) • >1000g: 4 (4.4%) • Rarely weekly 34 (37.8%) • Never: 4 (4.4%)	**Higher degree** • <500g: 8 (32%) • 500g-1000g: 5 (20%) • >1000g: 5 (20%) • Rarely weekly 5 (20%) • Never: 2 (8%)	
Marital status	**Not married** • <500g: 71 (32.1%) • 500g-1000g: 56 (25.3%) • >1000g: 14 (6.3%) • Rarely weekly 70 (31.7%) • Never: 10 (4.5%)	**Married** • <500g: 24 (31.2%) • 500g-1000g: 21 (27.3%) • >1000g: 8 (10.4%) • Rarely weekly 20 (26.0%) • Never: 4 (5.2%)	0.728
Income	**Less than 5000 SAR** • <500g: 50 (32.3%) • 500g-1000g: 33 (21.3%) • >1000g: 7 (4.5%) • Rarely weekly 57 (36.8%) • Never: 8 (5.2%)	**More than 5000 SAR** • <500g: 45 (31.5%) • 500g-1000g: 44 (30.8%) • >1000g: 15 (10.5%) • Rarely weekly 33 (23.1%) • Never: 6 (4.2%)	0.027
Protein intake (g/d)*	**Less than 100g/d** • <500g: 14 (32.6%) • 500g-1000g: 7 (16.3%) • >1000g: 3 (7.0%) • Rarely weekly 16 (37.2%) • Never: 3 (7.0%)	**150-200g/d** • <500g: 19 (24.7%) • 500g-1000g: 26 (33.8%) • >1000g: 5 (6.5%) • Rarely weekly 23 (29.9%) • Never: 4 (5.2%)	0.014
	100-150g/d • <500g: 41 (35.7%) • 500g-1000g: 34 (29.6%) • >1000g: 2 (1.7%) • Rarely weekly 35 (30.4%) • Never: 3 (2.6%)	**More than 200g/d** • <500g: 5 (38.5%) • 500g-1000g: 3 (23.1%) • >1000g: 3 (23.1%) • Rarely weekly 2 (15.4%) • Never: 0 (0.0%)	
Supplementary proteins	**Yes** • <500g: 65 (36.5%) • 500g-1000g: 49 (27.5%) • >1000g: 9 (5.1%) • Rarely weekly 46 (25.8%) • Never: 9 (5.1%)	**No** • <500g: 30 (25.0%) • 500g-1000g: 28 (23.3%) • >1000g: 13 (10.8%) • Rarely weekly 44 (36.7%) • Never: 5 (4.2%)	0.047
<400g of fruits and vegetables daily	**Yes** • <500g: 81 (32%) • 500g-1000g: 64 (25.3%) • >1000g: 19 (7.5%) • Rarely weekly 76 (30%) • Never: 13 (5.1%)	**No** • <500g: 14 (31.1%) • 500g-1000g: 13 (28.9%) • >1000g: 3 (6.7%) • Rarely weekly 14 (31.1%) • Never: 1 (2.2%)	0.918

Participants who don't count their daily protein intake were removed from the table for easy visualization.

In this study, 74% (n= 153) of males and 45.1% (n=41) of females consumed RM weekly; we found also that 84.7% (n=11) of participants with protein intake of more than 200 g/day, and 69.1%(n=123) of subjects using supplementary protein, 72.8% (n=104) of people with an income of more than 5000 SAR, 64.9% (n=164) of subjects who consumed <400 g of fruits and vegetables, and 66.7% (n=30) of subjects who consumed >400 g of fruits and vegetables consumed RM weekly. Nine-point-two percent of males (n=19), 23.1% (n=3) of participants with protein intake of more than 200 g/day, 10.8% (n=13) of subjects not taking supplementary protein, 10.5% (n=15) of people with an income of more than 5000 SAR, 7.5% (n=19) of subjects who consumed <400 g of fruits and vegetables, and 6.7% (n=3) of subjects who consumed >400 g of fruits and vegetables consumed more than 1000 g of RM weekly (Table 4).

In this sample, 28.5% (n=59) of males and females, 45.3% (n=19) of healthcare workers, 14.3% (n=4) of dietitians or sports coaches, 29.2% (n=74) of subjects who consumed <400 g of fruits and vegetables, and 24.4% of (n=11) subjects who consumed >400 g of fruits and vegetables consumed PM weekly. Eight percent of males (n=17), 23.1% (n=3) of participants with a protein intake of more than 200 g/day, 8.3% (n= 10) of subjects not taking supplementary protein, 7.9% (n=20) of subjects who consumed <400 g of fruits and vegetables, and 4.4% (n=2) of subjects who consumed >400 g of fruits and vegetables consumed >1000 g of PM weekly (Table 5).

Table 5: descriptive analysis: relationships between processed meat consumption (grams per week) and other variables.

Variable	Percentage n (%)		P-value
Gender	**Males** • <500g: 30 (14.5%) • 500g-1000g: 12 (5.8%) • >1000g: 17 (8.2%) • Rarely weekly 60 (29.0%) • Never: 88 (42.5%)	**Females** • <500g: 12 (13.2%) • 500g-1000g: 9 (9.9%) • >1000g: 5 (5.5%) • Rarely weekly 45 (49.5%) • Never: 20 (22.0%)	0.002
Education	**High school degree** • <500g: 11 (22.0%) • 500g-1000g: 3 (6.0%) • >1000g: 7 (14.0%) • Rarely weekly 17 (34.0%) • Never: 12 (24.0%)	**Bachelor degree** • <500g: 20 (15.0%) • 500g-1000g: 12 (9.0%) • >1000g: 8 (6.0%) • Rarely weekly 45 (33.8%) • Never: 48 (36.1%)	0.077
	College student • <500g: 11 (12.2%) • 500g-1000g: 4 (4.4%) • >1000g: 4 (4.4%) • Rarely weekly 37 (41.1%) • Never: 34 (37.8%)	**Higher degree** • <500g: 0 (0.0%) • 500g-1000g: 2 (8.0%) • >1000g: 3 (12.0%) • Rarely weekly 6 (24.0%) • Never: 14 (56.0%)	
Marital status	**Not married** • <500g: 34 (15.4%) • 500g-1000g: 19 (8.6%) • >1000g: 18 (8.1%) • Rarely weekly 79 (35.7%) • Never: 71 (32.1%)	**Married** • <500g: 8 (10.4%) • 500g-1000g: 2 (2.6%) • >1000g: 4 (5.2%) • Rarely weekly 26 (33.8%) • Never: 37 (48.1%)	0.070
Background	**Healthcare worker** • <500g: 7 (16.7%) • 500g-1000g: 7 (16.7%) • >1000g: 5 (11.9%) • Rarely weekly 15 (35.7%) • Never: 8 (19.0%)	**Dietitian, Sports coach** • <500g: 1 (3.6%) • 500g-1000g: 2 (7.1%) • >1000g: 1 (3.6%) • Rarely weekly 10 (35.7%) • Never: 14 (50.0%)	0.045

	Others • <500g: 34 (14.9%) • 500g-1000g: 12 (5.3%) • >1000g: 16 (7.0%) • Rarely weekly 80 (35.1%) • Never: 86 (37.7%)		
Protein intake (g/d) *	**Less than 100g/d** • <500g: 7 (16.3%) • 500g-1000g: 1 (2.3%) • >1000g: 3 (7.0%) • Rarely weekly 18 (41.9%) • Never: 14 (32.6%)	**150-200g/d** • <500g: 9 (11.7%) • 500g-1000g: 8 (10.4%) • >1000g: 3 (3.9%) • Rarely weekly 25 (32.5%) • Never: 32 (41.6%)	0.313
	100-150g/d • <500g: 19 (16.5%) • 500g-1000g: 11 (9.6%) • >1000g: 7 (6.1%) • Rarely weekly 39 (33.9%) • Never: 39 (33.9%)	**More than 200g/d** • <500g: 0 (0.0%) • 500g-1000g: 0 (0.0%) • >1000g: 3 (23.1%) • Rarely weekly 5 (38.5%) • Never: 5 (38.5%)	
Supplementary proteins	**Yes** • <500g: 29 (16.3%) • 500g-1000g: 13 (7.3%) • >1000g: 12 (6.7%) • Rarely weekly 55 (30.9%) • Never: 69 (38.8%)	**No** • <500g: 13 (10.8%) • 500g-1000g: 8 (6.7%) • >1000g: 10 (8.3%) • Rarely weekly 50 (41.7%) • Never: 39 (32.5%)	0.294
<400g of fruits and vegetables daily	**Yes** • <500g: 33 (13.0%) • 500g-1000g: 21 (8.3%) • >1000g: 20 (7.9%) • Rarely weekly: 89 (35.2%) • Never: 90 (35.6%)	**No** • <500g: 9 (20.0%) • 500g-1000g: 0 (0.0%) • >1000g: 2 (4.4%) • Rarely weekly: 16 (35.6%) • Never: 18 (40.0%)	0.209

Participants who don't count their daily protein intake were removed from the table for easy visualization

In this sample, 65.7% (n=159) of participants who had never heard about nitrites and N-nitroso compounds, 65.3% (n=177) of subjects who did not know about these compounds, and 80% (n=16) of participants thought they were unrelated to cancer development consumed RM weekly. In addition, 29.8% (n=72) of participants who had never heard about nitrites and N-nitroso compounds, 28.4% (n=77) of subjects who did not know about these compounds, and 45% (n=9) of participants thought they were unrelated to cancer development consumed PM weekly (Table 6).

DISCUSSION

This study aimed to investigate the knowledge of gym users on RM and PM and their eating behaviors; analyze whether sports, social and demographic characteristics, and nutritional factors could affect RM and PM consumption; and assess whether less understanding of the possible risks associated with consuming RM and PM is related to higher consumption of these types of food.

The major findings indicate that some factors were associated with higher RM consumption, such as being male, high protein intake (>200 g/day), supplementary protein intake, and having a good income (more than 5000 SAR) (p= 0.000, 0.014, 0.047, and 0.027). This is in line with previous similar studies which indicated that male gender, higher protein intake per day, and wealth were associated with higher RM consumption.[15,25,28]

Table 6: Relationship between awareness of red meat and processed meat risks and their consumption (grams per week)

Percentage n (%)		P-value
Question: Have you ever heard of nitrites and N-nitroso compounds (NOCs)?		
Yes **<500g**: RM 21 (37.5%), PM 7 (12.5%) **500g-1000g:** RM 12 (21.4%), PM 3 (5.4%) **>1000g:** RM 2 (3.6%), PM 3 (5.4%) **Rarely weekly:** RM 16 (28.6%), PM 21 (37.5%) **Never:** RM 5 (8.9%), PM 22 (39.3%)	**No** **<500g**: RM 74 (30.6%), PM 35 (14.5%) **500g-1000g:** RM 65 (26.9%), PM 18 (7.4%) **>1000g:** RM 20 (8.3%), PM 19 (7.9%) **Rarely weekly:** RM 74 (30.6%), PM 84 (34.7%) **Never:** RM 9 (3.7%), PM 86 (35.5%)	**RM:** 0.263 **PM:** 0.900
Question: Do you know what is nitrites and N-nitroso compounds (NOCs)?		
Yes **<500g**: RM 10 (37.0%), PM 6 (22.2%) **500g-1000g:** RM 5 (18.5%), PM 1 (3.7%) **>1000g:** RM (7.4%), PM 1 (3.7%) **Rarely weekly:** RM 8 (29.6%), PM 9 (33.3%) **Never:** RM 2 (7.4%), PM 10 (37.0%)	**No** **<500g**: RM 85 (31.4%), PM 36 (13.3%) **500g-1000g:** RM 72 (26.6%), PM 20 (7.4%) **>1000g:** RM 20 (7.4%), PM 21 (7.7%) **Rarely weekly:** RM 82 (30.3%), PM 96 (35.4%) **Never:** RM 12 (4.4%), PM 98 (36.2%)	**RM:** 0.856 **PM:** 0.655
Question: Do you think that an excessive consumption of sodium and potassium nitrite/nitrate can be correlated to cancer development?		
Yes **<500g:** RM 6 (33.3%), PM 1 (5.6%) **500g-1000g:** RM 1 (5.6%), PM 1 (5.6%) **>1000g:** RM 0 (0.0%), PM 1 (5.6%) **Rarely weekly:** RM 10 (55.6%), PM 8 (44.4%) **Never:** RM 1 (5.6%), PM 7 (38.9%)	**No** **<500g:** RM 7 (35.0%), PM 5 (25.0%) **500g-1000g:** RM 5 (25.0%), PM 2 (10.0%) **>1000g:** RM 4 (20.0%), PM 2 (10.0%) **Rarely weekly:** RM 2 (10%), PM 7 (35.0%) **Never:** RM 2 (10.0%), PM 4 (20.0%)	**RM:** 0.033 **PM:** 0.731

I don't know
    <500g: RM 82 (31.5%), PM 36 (13.8%)
    500g-1000g: RM 71 (27.3%), PM 18 (6.9%)
    >1000g: RM 18 (6.9%), PM 19 (7.3%)
    Rarely weekly: RM 78 (30.0%), PM 90 (34.6%)
    Never: RM 11 (4.2%), PM 97 (37.3%)		

Surprisingly, PM consumption was higher among health workers than those from other backgrounds in this study population. This might be due to a potential lack of teaching about diet and nutrition in healthcare-related university curricula; a previous study showed a lower level of knowledge regarding the potential dangers of RM-PM consumption among participants with a healthcare background.[25] In contrast, being a dietitian or sports coach was associated with lower PM consumption in this study (p=0.045), which is consistent with the previous Turkish study on the eating habits of sports coaches that showed that only 9.3% of participants consumed red meat, turkey, and chicken.[27] RM and PM consumption only exceeded the cut-off suggested by the WCRF by 33.2% and 28.6%.[1] This agrees with the national study conducted in 2013, which showed that the mean daily RM and PM consumed by sedentary Saudi adults were 44.2 g/day and 4.8 g/day.[26] The WCRF/AICR recommends eating at least 400 g of fruits and vegetables daily.[1] In this study, the majority (84.9%) of the participants consumed less than 400 g of fruits and vegetables daily, which corresponds to the mean daily consumption of 70.9 g/day and 111.1 g/day for fruits and vegetables reported in a previous study.[26] These data are alarming, and increased efforts to improve eating habits in Saudi Arabia are required.

Regarding knowledge outcomes, the overwhelming majority of participants (81.2%) had never heard about nitrites and N-nitroso compounds. These results are similar to those of previous studies performed before and after the IARC statement, indicating a need to increase awareness about RM and PM and their potential dangers.[16,25] Knowing about nitrites and N-nitroso compounds and their relationship to cancer

development was associated with a lower consumption of RM in this study population (p=0.033). In a previous Italian study, approximately 66.3% of participants lacked the knowledge that these compounds can be linked to cancer development.[25] Regarding HCAs and PAHs produced through barbecuing, broiling, and griddling,[1,6,7] approximately 33.2% declared that they used these cooking methods most of the time/always; this value is lower than that of the previous Italian study that indicated that 52.49% of the participants used these cooking methods most of the time/always.[25] The presence of HCAs and PAHs is also influenced by the degree of cooking; [7] However, only 5.4% of the participants consumed overcooked meat, similar to the results of a previous study which reported that approximately 4% of participants consumed overcooked meat.[25]

In contrast to previous studies which showed that marital status could influence diet, it did not seem to affect RM and PM consumption in this study population (p>0.05).[25,29-30] This could be because most participants were singles and in the 18–24 years age group. Education level also did not affect RM and PM consumption in our sample, which is similar to the findings of a previous Mexican study that demonstrated that there were no associations between education and the likelihood of RM-PM consumption.[28] This might be explained by a poor understanding of RM and PM among the overwhelming majority of participants.

This study had some strengths and limitations that should be appreciated. One of the main strengths is that it is one of the first studies conducted among gym users in Saudi Arabia that focused on eating habits. It is also one of the first studies on consumption and awareness of the possible risks of RM and PM consumption, conducted after the IARC statements.[3] Furthermore, the questionnaire was distributed online, making it possible to reach participants from different backgrounds. The main limitation is the cross-sectional methodology used, which makes the recognition of causal associations unfeasible. Moreover, the results of this study cannot be representative of the general Saudi Arabian population; however, its findings could help in investigating the characteristics of the gym users subgroup. Another limitation is that the elements of eating habits may have impacted participants when they answered the knowledge elements. Finally, recall bias could be a drawback of using a self-administered questionnaire as a method of data collection.

CONCLUSION

In conclusion, our study showed that increased efforts to execute educational campaigns on RM and PM are required. Special focus should be placed on male athletes that utilize nutrition to enhance performance and on people of good socio-economic status. In addition, it is important to establish educational programs in gyms, and subsequently, work should be carried out to increase awareness about these risky eating habits. Finally, it is advisable to reach the general population through other means, such as conducting educational campaigns in schools, governmental offices, and shopping malls in the near future.

Conflict of Interest
The authors declare that there is no conflict of interest relevant to this article.

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