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Physical Activity and CRC

RESEARCH ARTICLE

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Association of Physical Activity and Sedentary Behavior with Colorectal Cancer Risk in Moroccan Adults: A Large-Scale, Population-Based Case–Control Study

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Abstract

Background: Physical activity has been associated with a lower risk of colorectal cancer in studies mainly conducted in high-income countries, while sedentary behavior has been suggested to increase CRC risk. In this study, we aimed to investigate the role of physical activity and sedentary behavior on CRC risk in the Moroccan population. **Methods:** A case-control study was conducted involving 1516 case-control pairs, matched on age, sex and center in five university hospital centers. A structured questionnaire was used to collect information on socio-demographics, lifestyle habits, family history of CRC, and non-steroidal anti-inflammatory drug (NSAID) use. Information on physical activity and sedentary behavior were collected by the Global Physical Activity Questionnaire (GPAQ). For each activity (work, household, and recreational activities), a metabolic equivalent (MET) was calculated using GPAQ recommendations. Conditional logistic regression models were used to assess the association between physical activity, sedentary behavior and the risk of overall CRC, colon cancer, and rectal cancer taking into account other CRC risk factors. **Results:** High level of physical activity was associated with lower risk of rectal cancer, colon cancer, and overall CRC, the adjusted odds ratios (ORa) for the highest versus the lowest level of activity were 0.67 (95% CI: 0.54-0.82), 0.77 (95% CI: 0.62-0.96), and 0.72 (95% CI: 0.62-0.83), respectively. In contrast, sedentary behavior was positively associated with rectal cancer risk (ORa=1.19, 95% CI: 1.01-1.40), but was unrelated to colon cancer risk (ORa=1.02, 95% CI: 0.87-1.20). **Conclusion:** We found an inverse association between physical activity and CRC risk in the Moroccan population, and a positive association between sedentary behavior and rectal cancer risk. Considering that one-third of the total population studied had a sedentary lifestyle, these results may be used to improve strategies of public health suitable for Moroccan population.

Keywords: Physical activity- sedentary behavior- colorectal cancer risk- Morocco

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Introduction

Colorectal cancer is the third most commonly diagnosed cancer worldwide with 1.8 million cases, and the second in terms of mortality with 881,000 deaths (Ferlay et al., 2018; Bray et al., 2018). There is a wide geographical variation in the distribution of the CRC incidence around the world (Bray et al., 2018; BW and CP). In 2018, incidence rates were generally from 2 to 3-fold higher in high income countries compared with low and middle income countries (LMIC) (Bray et al., 2018). However, differences in mortality rates between these two regions are smaller, specifically because CRC patients living in LMIC discover their disease at a later stage (Bray et al., 2018). In Morocco, for example, from 2008 to 2012, there is increasing tendency in the CRC incidence with age standardized increases in incidence rates of 3.8 to 8.4 and from 2.6 to 7.4 per 100,000 in men and women, respectively (Fondation Lalla Salma Prévention et Traitement des Cancers).

It is well known that CRC risk is influenced by both, genetic and environmental factors (Kuipers et al., 2015).

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A range of modifiable factors including smoking, alcohol intake, food consumption (e.g. red and processed meat, fibre, calcium) and obesity can influence the risk of developing CRC (Eaglehouse et al., 2017; Abar et al., 2018). According to the World Cancer Research Fund/ American Institute for Cancer Research, the evidence on the association between all types of physical activity (occupational, household, transport and recreational) and reduced CRC risk has been classified as convincing (World Cancer Research Fund/ Institute for Cancer Research 2018).

Based on observational epidemiological evidence, the decrease in the risk associated to steady physical activity is estimated to be 25–30%, when comparing the most active to least active participants in these studies (Chao et al., 2004; Friedenreich et al., 2006; Wolin et al., 2007, 2009). Sedentary behavior is positively and independently of PA associated with an increased risk of colorectal cancer (Kerr et al., 2017). This evidence was based mainly on studies conducted among western populations. However, less information is available on the association between physical activity and CRC risk in developing countries.

Several studies have investigated the associations between physical activity, dietary habits and health outcomes in Morocco, but these mainly focused on Moroccan teenagers and adolescents (López et al., 2012; Hamrani et al., 2015; El-ammari et al., 2017). Morocco is a fast-growing country, experiencing an important epidemiological and nutritional transition (Belahsen, 2014; Ronto et al., 2018). Urbanization and economical growth have been identified as the main determinants of reduced physical activity levels among this population where 24% of women and 9% of men were classified in the lowest physically active group (Najdi et al., 2011).

To obtain evidence on a link between physical activity and CRC in the Moroccan context, we studied the association between physical activity and sedentary behavior and CRC risk in a population-based case control study.

Materials and Methods

Study population

A case control study was conducted from September 2009 until February 2017 in five Moroccan University hospitals located in Rabat, Casablanca, Oujda, Fez, and Marrakech (Najdi et al. 2011).

Inclusion criteria for cases and controls

Details of this study have been reported elsewhere(Fondation Lalla Salma Prévention et Traitement des Cancers). Briefly, only newly diagnosed CRC cases were recruited in this study. Controls were randomly selected from outpatients accompanying other patients and visitors that were healthy disease-free and recruited in the same time-window as cases. Cases and controls were individually matched on age (± 5 years), sex, and center.

Other eligibility criteria included the following: aged at least 18 years old, had not received any treatment (radiotherapy, chemotherapy and hormone-therapy), psychiatric problems, diabetes mellitus, and cardiovascular diseases, and an ability to communicate and carry out the interview.

Participation rate

In this study, the participation rate was 97.5% (1,516/1,555) for cases and 75.8% (1,516/2,000) for controls.

Ethical procedure

The protocol of this study has been approved by the ethics Committee at the University of Fez. Before starting the study, all participants provided written informed consent to participate.

Data collection

Trained interviewers collected data using a structured questionnaire. Information on sociodemographic characteristics, clinical, lifestyle and dietary data were collected via face-to-face interview. Socio-demographic data included age, sex, center, residency, marital status, educational level, and monthly income. Clinical data included the type and the stage of cancer, family history specially related to CRC (first and second-degree relatives), and the use of non-steroidal anti-inflammatory drugs (NSAID).

To estimate the intensity of physical activity, it is necessary to take into account the frequency, time, intensity, and type of physical activity (work, home and recreational activities) (World Health Organization). The Global Physical Activity Questionnaire (GPAQ) was used to collect this detailed information on physical activity and the Metabolic Equivalent of Task (MET) was calculated for each participant according to GPAQ guideline (World Health Organization). The physical activity intensity was obtained by dividing the METs into three categories: low intensity (<600 MET-minutes per week), moderate intensity (600–3,000 MET-minutes per week), and vigorous intensity (≥3,000 MET-minutes per week). Information about sedentary behavior was collected as time spent during a typical sitting or reclining per day. A sedentary person was defined as spending more than 4 hours in a sitting or lying position, excluding time spent a sleep (Sigmundová et al., 2015).

Information on alcohol consumption was collected and classified into never or current consumers, smoking status was defined according to the International Union Against Tuberculosis and Lung Disease guide (never, current and ex-smokers) (Slama et al., 2008).

A validated food frequency questionnaire (FFQ) was used for dietary assessment (El Kinany et al., 2018). This FFQ included 255 items to estimate food intake in the Moroccan population. Food consumption frequencies were divided into 8 categories: (never, 1-3 times/month, once a week, 2-4 times/week, 5-6 times/week, once a day, 2-3 times/day, and equal or more than 4 times/day).

Anthropometric measurements, including weight and height, were extracted from medical records. Body mass index (BMI; kg/m2) was calculated as the ratio of the weight divided by the square of height in meters. BMI was classified using cut-off points recommended by WHO [29]: underweight [16–18.5[kg/m^2, normal [18.5–25[kg/

m^2, overweight [25–30[kg/m^2), obesity for BMI ≥30 kg/m^2. For BMI subgroups, risk estimates for all subgroups were taken and classified in "low" and "high" BMI groups. In general, "low" BMI groups represented those in the" Underweight"(BMI<24.9 kg/m^2) or "normal" (BMI<25 kg/m^2) range of BMI. Effect estimates that were classified as "high" BMI generally represented those in the "overweight" (25 ≤BMI < 30 kg/m^2) or "obese" (BMI ≥ 30 kg/m^2) ranges of BMI.

Statistical analysis

Exclusion criteria prior to commencing the analyses included: participants with unspecified primitive cancer (n=7), cases with old biopsies (6 cases), participants with missing dietary data (n=10), duplicate records (n=2), unmatched records (n=8) and participants with the lowest and highest 1% of the distribution of the ratio between energy intake and energy requirement (n=30).

Descriptive analyses were conducted using frequencies for categorical variables and means ± standard deviation (SD) for continuous variables. To assess the difference between cases and controls, we used the Mc-Nemar test for categorical variables and a t-test for matched samples for analyzing continuous variables. A description of the study population was published previously (El Kinany et al., 2019).

Conditional logistic regression models were utilised to evaluate the associations between the intensity of physical activity and sedentary behavior and CRC risk. The adjusted odds ratio (ORa) and 95% confidence interval (95% CI) were estimated taking into account relevant confounders: age (years), residency (urban, rural), education level (illiterate, primary, secondary, higher), monthly income (low, medium, high), BMI categories (normal, underweight, overweight and obesity), smoking status (never smoker, ex-smoker and current smoker), alcohol (yes, no), family history of CRC (yes, no), sedentary behavior (yes, no), NSAID use (yes, no), intake of red and processed meat (continuous, g/day), fiber (continuous, g/day), calcium (continuous, g/day), and total energy intake (continuous, kcal/day). As body size/adiposity is potentially on the causal pathway linking physical activity and sedentary activities with colorectal cancer, we also performed all models with and without adjustment for BMI categories. Further adjustment for previous screening of colorectal cancer resulted in virtually unchanged risk estimates, so this variable was not involved in the multivariable models (supplementary material- Tables 1 and 2). Trend tests across physical activity categories were calculated by entering the categorical exposure variables into the models as continuous variables. In addition to overall CRC, analyses were also undertaken for colon cancer and rectal cancer for sexes combined and for men and women separately. Heterogeneity of associations by sex and across anatomical cancer subsites was assessed by calculating X2 statistics. We examined effect modification by BMI, tests of interaction were based on a Wald test of the interaction term. The interaction with BMI was not statistically significant for colon and rectal cancer. Only for overall CRC, we found a borderline significant interaction between BMI and PA.

Results

Table 1 presents the general socio-demographic characteristics and potential confounders for this case-control study. Compared to controls, the mean age of cases was slightly higher (56.45 ± 13.95 years vs. 55.50 ± 13.70). Marital status and residency were similarly distributed between cases and controls. When cases and controls were compared, cases were more likely to be smokers and to have a higher occurrence of family history of CRC. Concerning CRC anatomical location, 50.2% cases had colon cancer and 49.8% had rectal cancer.

Table 2 shows the distribution of physical activity intensity in MET-minutes/week and sedentary behavior among CRC cases and controls. More than a quarter of the female and the men cases ranked in the low physical activity category and had a sedentary behavior. In addition, more than one-third of cases and controls (women and men) had a sedentary lifestyle.

Table 3 shows the crude and the adjusted Odds Ratios for CRC risk and intensity of physical activity and sedentary behavior. Moderate and higher levels of physical activity comparing to the low physical activity intensity

Table 1. Adjusted Odds Ratio for Physical Activity Intensity and Sedentary Behavior in CRC Cases and Controls by Anatomical Location of the CRC (Colon or Rectum) (N=2906).

	MET-min/week	Colon cancer (N=729)		Rectal cancer (N=724)		Colorectal cancer (N=1453)	
		OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)
Physical activity							
Low	<600 MET	1	1	1	1	1	1
Moderate	600–3000 MET	0.85 (0.72-1.00)	0.88 (0.74-1.04)	0.69 (0.58-0.81)	0.71 (0.60-0.85)	0.77 (0.68-0.87)	0.79 (0.70-0.89)
High	≥3000 MET	0.81 (0.66-0.99)	0.77 (0.62-0.95)	0.68 (0.56-0.83)	0.65 (0.53-0.80)	0.74 (0.64-0.86)	0.71 (0.61-0.82)
p-trend			0.05		0.001		0.09
Sedentary behavior							
No	< 4 hours	1	1	1	1	1	1
Yes	≥ 4 hours	1.05 (0.90-1.21)	1.02 (0.87-1.20)	1.13 (0.97-1.31)	1.17 (0.99-1.37)	1.08 (0.97-1.20)	1.09 (0.97-1.22)

*Crude Odds Ratio (ORc); Crude model analysis adjusted; ¥Adjusted Odds Ratio (ORa); Multivariable model: conditional logistic regression using age in years, residence (urban, rural), education level (illiterate, primary, secondary, higher), monthly income (low, medium, high), smoking status (never smoker, Ex-smoker and current smoker), Non-steroidal anti-inflammatory drugs (yes or no), total energy intake (continuous), intakes of red processed meat and dietary fiber (both continuous), calcium (continuous), family history of colorectal cancer(yes or no).

Table 2. Adjusted Odds Ratio for Physical Activity Intensity and Sedentary Behavior in CRC Cases and Controls by Sex Stratification) (N=2906).

		Men					
	MET-min/week	Colon cancer (N=348)		Rectal cancer (N=368)		Colorectal cancer (N=716)	
		OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)
Physical activity							
Low	<600 MET	1	1	1	1	1	1
Moderate	600–3000 MET	0.79 (0.60-1.05)	0.87 (0.65-1.15)	0.72 (0.56-0.92)	0.79 (0.62-1.02)	0.75 (0.62-0.90)	0.83 (0.69-0.99)
High	≥3000 MET	0.73 (0.53-1.00)	0.72 (0.53-1.01)	0.66 (0.50-0.87)	0.66 (0.49-0.87)	0.69 (0.56-0.85)	0.69 (0.56-0.86)
p-trend			0.17		0.01		0.001
Sedentary behavior							
No	< 4 hours	1	1	1	1	1	1
Yes	≥ 4 hours	0.97 (0.77-1.21)	1.02 (0.80-1.29)	1.13 (0.92-1.40)	1.26 (1.01-1.58)	1.05 (0.91-1.23)	1.13 (0.96-1.33)
		Women					
	MET-min/week	Colon cancer (N=381)		Rectal cancer (N=356)		Colorectal cancer (N=737)	
		OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)	OR_c*(95% CI)	OR_a¥(95% CI)
Physical activity							
Low	<600 MET	1	1	1	1	1	1
Moderate	600–3000 MET	0.87 (0.69-1.08)	0.85 (0.68-1.07)	0.66 (0.52-0.83)	0.65 (0.51-0.82)	0.76 (0.65-0.89)	0.76 (0.64-0.89)
High	≥3000 MET	0.88 (0.64-1.18)	0.77 (0.56-1.05)	0.71 (0.53-0.97)	0.66 (0.49-0.90)	0.79 (0.64-0.98)	0.73 (058-0.90)
p-trend			0.2		0.001		0.001
Sedentary behavior							
No	< 4 hours	1	1	1	1	1	1
Yes	≥ 4 hours	1.10 (0.90-1.35)	1.03 (0.83-1.28)	1.12 (0.90-1.38)	1.07 (0.85-1.35)	1.11 (0.96-1.28)	1.05 (0.90-1.23)

*Crude Odds Ratio (ORc); Crude model analysis; ¥Adjusted Odds Ratio (ORa); Multivariable model: conditional logistic regression using age in years, residence (urban, rural), education level (illiterate, primary, secondary, higher), monthly income (low, medium, high), smoking status (never smoker, Ex-smoker and current smoker), alcohol consumption (yes, no), Non-steroidal anti-inflammatory drugs (yes or no), total energy intake (continuous), intakes of red processed meat and dietary fiber (both continuous), calcium (continuous), family history of colorectal cancer(yes or no); +Adjusted Odds Ratio (ORa) for women; Multivariable model: conditional logistic regression using age in years, residence (urban, rural), education level (illiterate, primary, secondary, higher), monthly income (low, medium, high), Non-steroidal anti-inflammatory drugs (yes or no), total energy intake (continuous), intakes of red processed meat and dietary fiber (both continuous), calcium (continuous), family history of colorectal cancer(yes or no).

were associated with reduced risk of rectal cancer and CRC overall in the crude and the multivariable models. For rectal cancer, comparing to the low physical activity intensity, the estimated risks for moderate and high physical activity intensity were respectively ORa=0.72, 95% CI: 0.61-0.85 and ORa=0.67, 95% CI: 0.54-0.82, p-trend<0.001 respectively. For CRC overall, comparing to the low physical activity intensity the estimated risks for moderate and high physical activity intensity were ORa=0.80, 95% CI: 0.71-0.90 and ORa=0.72, 95% CI: 0.62-0.83, p-trend<0.001 respectively. For colon cancer, an inverse association was found for high activity, but it did not reach the significance threshold (ORa=0.77, 95% CI: 0.62-0.96, p-trend=0.07). We found a borderline significant interaction between BMI and PA for overall CRC (p-interaction = 0.05); however, inverse associations were found for both the low and high BMI strata (Table 3). No significant interactions between BMI and PA were found for colon (p-interaction = 0.27) and rectal cancer (p-interaction = 0.12) were observed. The inverse association we found for physical activity and CRC risk was consistent across low and high BMI groups. (supplementary material - table 3 and 4).

No significant association was observed between sedentary behavior and CRC risk; except for rectal cancer for which sedentary behavior was positively associated (ORa=1.19, 95% CI: 1.01-1.40).

Table 4 shows crude and adjusted ORs and 95% CIs by anatomical location of the tumour (colon or rectum) by for physical activity intensity and sedentary behavior for men and women separately. Before and after adjustment for confounding factors, moderate and higher levels of physical activity were associated with reduced risk of overall CRC in men, the adjusted OR were 0.83 (95% CI:

Table 3. An Interaction by BMI for the Association between PA and CRC Overall, Colon and Rectal Cancer (N=2906).

Physical activity	MET-min/week	Colon cancer (N=729)	Rectal cancer (N=724)	Colorectal cancer (N=1453)
			BMI (Kg/m^2)	
		p-interaction	p-interaction	p-interaction
Low	<600 MET			
Moderate	600–3000 MET	0.27	0.12	0.05
High	≥3000 MET			

Table 4. Adjusted Odds Ratio for Physical Activity Intensity in CRC Cases and Controls by BMI Stratification (N=2906).

Physical activity	MET-min/week	Colorectal cancer	
		BMI (Kg/m^2)	
		Low BMI (N=1289)	High BMI (N=1617)
		OR$_a$ [¥](95% CI)	OR$_a$ [¥](95% CI)
Low	<600 MET	1	1
Moderate	600–3000 MET	0.76 (0.62-0.92)	0.83(0.71-0.97)
High	≥3000 MET	0.64 (0.50-0.92)	0.78(0.64-0.95)
p-trend		0.001	0.02

[¥]Adjusted Odds Ratio (OR$_a$); Multivariable model: conditional logistic regression using age in years, residence (urban, rural), education level (illiterate, primary, secondary, higher), monthly income (low, medium, high), smoking status (never smoker, Ex-smoker and current smoker), Non-steroidal anti-inflammatory drugs (yes or no), total energy intake (continuous), intakes of red processed meat and dietary fiber (both continuous), calcium (continuous), family history of colorectal cancer(yes or no).

0.69-0.99) and 0.69 (95% CI: 0.56-0.85) p-trend<0.001 respectively. Similar relationships were found in women for overall CRC; the adjusted OR=0.76, 95% CI: 0.65-0.89 for moderate PA and OR=0.75, 95% CI: 0.60-0.93 for high PA, p-trend<0.001, P-heterogeneities=0.001. For colon cancer, in both men and women, an inverse association was found for moderate and high PA, but it did not reach the significance threshold (P-heterogeneities=0.07).

For rectal cancer, in women, moderate and higher levels of physical activity were associated with reduced risk of rectal cancer (ORa=0.72, 95% CI: 0.61-0.85) and (ORa=0.67, 95% CI: 0.54-0.82), p-trend<0.001 respectively. In men, an inverse association was only found for high levels of PA, ORa=0.66, 95% CI: 0.50-0.88, p-trend<0.02, P-heterogeneities=0.001.

For sedentary behavior, a positive association was limited to rectal cancer ORa=1.28, 95% CI: 1.02-1.61 but not colon cancer, and only for men (P-heterogeneity=0.001). In addition, no association was found between sedentary behavior and risks of overall CRC and colon cancer for both men and women.

Discussion

In this CRC case-control study carried out in Morocco, we examined the association between physical activity, sedentary behavior and CRC risk. We found that a high level of physical activity was associated with reduced risks of colon cancer, rectal cancer and overall CRC. For sedentary behavior, a positive association was found for rectal cancer, but not for overall CRC and colon cancer.

We found an inverse association between moderate and high intensity activity and overall CRC risk among men and women. Similar inverse associations between higher levels of physical activity and CRC risk have been reported by multiple other studies (Wolin and Tuchman, 2011; Golshiri et al., 2016; Ghafari et al., 2016). The inverse association we found for physical activity and CRC risk was consistent across low and high BMI groups.

We found that colon cancer was inversely associated with high intensity of physical activity. Multiple studies showed an inverse association between colon cancer risk and physical activity (Gerhardsson et al., 1988; Giovannucci et al., 1995; Thune and Lund, 1996; Colditz et al., 1997; Lee, 2003; Morris et al., 2018). For sexes combined, we found an inverse association for physical activity and colon cancer risk, with similar magnitudes found for these inverse associations for men and women separately. Similar results were found by a large pooled analysis that also reported inverse associations between physical activity and colon cancer for both, men and women (Gerhardsson et al., 1988; Giovannucci et al., 1995; Thune and Lund ,1996; Colditz et al., 1997; Lee, 2003; Morris et al., 2018). In this current study, moderate and high intensity activity was inversely associated with rectal cancer risk for both men and women and sexes combined. Our findings are in agreement with the study published by **Moore et al., ???** that showed a decrease in the risk of CRC and rectal cancer in individuals with vigorous physical activity (Lee et al., 1991; Slattery et al., 2003). However, the World Cancer Research Fund/ American Institute for Cancer Research did not find any association between physical activity and rectal cancer risk (Lee et al., 1991; Thune and Lund, 1996; Robsahm et al., 2013). A cohort study in the Netherlands suggests that non-occupational physical activity was associated with rectal cancer in women (Simons et al., 2013a).

Emerging evidence suggests that sedentary behavior may be a risk factor for CRC, independent of PA (Lynch, 2010; Simons et al., 2013; Schmid and Leitzmann, 2014; Cao et al., 2015; Kerr et al., 2017). In a meta-analysis, sedentary behavior as specified by time spent watching TV, occupational sitting time, and total sitting time was associated with a 54%, 24%, and 24% increased risk of colon cancer, respectively (Schmid and Leitzmann, 2014). In a more recent prospective analysis in the UK Biobank (Morris et al., 2018), greater television watching time, but not time spent on a computer, was associated with higher colon cancer risk; with no associations found for rectal cancer risk. In the current study, rather than domain-specific activities, sedentary behavior was defined as the time spent during a typical day sitting or reclining. Consequently, we were unable to assess how specific sedentary behaviors were associated with CRC risk. Substantial challenges also remain to translate the current understanding of the impact of sedentary behavior on CRC risk into interventions with possible clinical impact. Subjective measures based on self-reported information

are prone to measurement error, whereas more objective measures are costly and lacking information on specific domains of sedentary behavior (Healy et al., 2011). Additional studies are needed to examine the possible role of sedentary behavior in colorectal cancer development.

The main mechanisms that could explain the potentially beneficial effect of physical activity on the risk of CRC are associated to its effects on weight and adiposity (mainly abdominal) and favorable effects on circulating levels of insulin and insulin-like growth factor 1 (IGF-1) which promote cellular proliferation (Gerhardsson et al., 1988; Giovannucci et al., 1995; Thune and Lund 1996; Colditz et al., 1997; Lee, 2003; Morris et al., 2018).The physiological mechanisms of movement from sitting to standing may improve several functions of the human body like: glucose regulation that will be achieved by increasing insulin sensitivity and non–insulin-dependent glucose in muscles during regular physical activity (Short, 2013). Physical activity can also lower colorectal cancer risk by stimulating digestion and reducing transit time through the intestine thus reducing the time of exposure of the colonic mucosa and fecal contents to food-borne carcinogens (Gerhardsson et al., 1988; Giovannucci et al., 1995; Thune and Lund, 1996; Colditz et al., 1997; Lee, 2003; Morris et al., 2018). In addition, being active can mask mitochondrial aging in the muscle and increases blood flow, adrenergic signaling, and shear stress that enhances vascular homeostasis of the endothelium (Brierley et al., 1996; Olufsen et al., 2005; Pagan et al., 2018), all of which have the potential to regulate tumor growth and tumor metabolism (Brierley et al., 1996; Kerr et al., 2017). Lower sedentary behaviors have also been associated with lower insulin levels and lower inflammation, they convincingly increase the risk of weight gain, overweight and obesity (Gerhardsson et al., 1988; Giovannucci et al., 1995; Thune and Lund, 1996; Colditz et al., 1997; Lee, 2003; Morris et al., 2018).

The urban population in Morocco has increased from 29% in 1960 to 62.4% in 2018 (El Rhazi et al., 2020) while undergoing an economical transition, characterized by increasing industrialization and accompanied by an increased sedentary lifestyle and decreased physical activity. Leisure (walking and cycling) and labor activities have been replaced by mechanized activities (Batnitzky, 2008). Moroccan rural residents are more likely to participate in all forms of physical activity (at work, play sports, transport, etc.) than urban residents, only 14.2% of rural residents did not meet WHO recommendations (El-ammari et al., 2017). Generally, in the Arab world, the prevalence of physical activity was higher in men than in women, due to cultural and social factors and restrictions on external exercises, especially for women. This was confirmed by prevalence results showing that the lowest physically active class was higher in women (24%) compared to men (9%) among the Moroccan adult population in 2011 (Najdi et al., 2011). The sedentary problem further increased due to changes in adolescent behaviors. The prevalence of physical inactivity was 79.5% and sedentary behavior was 36.5% among Moroccan adolescents in 2017 (El-ammari et al., 2017). It is women who are more likely to have sedentary behaviors 26% compared to men 16.1% (El-ammari et al., 2017). The urbanization and the globalization are the principal determinants of low physical activity among Moroccan adults. Low levels of physical activity and increased sedentary behavior have been associated with increasing health risks, calling for appropriate interventions and a political and educational framework to combat the pandemic of sedentary behavior among children, adolescents, and adults in Morocco. Increasing the frequency and the active time in school-based sports and enhancing public awareness about the healthy lifestyle may reduce the prevalence of physical inactivity. As highlighted in the World Health Organization Global action plan on physical activity 2018–2030, all stakeholders should support the strengthening of the evidence and data systems, particularly in LMICs (World Health Organization).

This study had several strengths. This study is among the first to investigate the associations between intensity of physical activity, sedentary behavior and CRC risk in North Africa in such a large sample. The relatively large number of the participants permitted analyses by sex and across colorectal subsites. Further, the detailed information on the exposure collected from participants enabled us to carefully adjust for known colorectal cancer risk factors.

Potential limitations of this study are the complexity of the physical activity and sedentary quantifications. Physical activity measurements were obtained based on the GPAQ, for which the questions focused on the study year, without considering physical activity changes during the life course. In addition, underestimations of the physical activity levels are probable and may especially be an issue among housewives (El-ammari et al., 2017).

To conclude, we found an inverse association between intensity of physical activity and CRC risk in the Moroccan population, and a positive association between sedentary behavior and rectal cancer risk. Considering one-third of the study population had a sedentary lifestyle, these results can be used to establish public health strategies adapted to the Moroccan population.

Abbreviations

BMI: Body Mass Index.
CI: Confident Interval.
CRC: Colorectal cancer.
FFQ: Food Frequency Questionnaire.
IARC: International Agency for Research on Cancer.
GPAQ: Global Physical Activity Questionnaire.
LMIC: Low and Middle Income Countries.
MET: Metabolic Equivalent Task.
NSAID: Non-Steroidal Anti-Inflammatory Drugs.
SD: Standard Deviation.
WCRF/AICR: World Cancer Research Fund/American Institute for Cancer Research.

IARC disclaimer:

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Author Contribution Statement

The study idea and its design were conceived by ZH and KE. The analyses and the interpretation of the data were led by the same doctors. KR conceived the study idea, its design, and led the analyses and interpretation of the data and supervised the drafting. IH, NM, MG, MK, MD, HAB, BA and AA participated in the conception and the design of the study. AM, BK and IMZ contributed to the conception of the study, and the collection of data. All authors have read and approved the manuscript.

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Ethics approval and consent to participate

Ethical clearance was acquired from the Ethics Committee at University of Fez. All subjects were informed about their role in this study and gave written formal consent before being interviewed Consent for publication

Availability of data and material

Under the ethical committee policy of the University of Fez, data involving participants or patients cannot be publicly shared. Individual requests for further information on the study can be sent to the corresponding author.

Conflict of interest

On behalf of all authors, the corresponding author declares that there is no conflict of interest.

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