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The Association of Physical Activity with Health Indices and Healthcare Utilization

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Abstract

This study aimed to examine the association between physical activity and individuals' health status, healthcare utilization, socio-demographic characteristics, and health behaviors in a large representative sample from Northern Greece. A cross-sectional study was conducted involving 1227 participants (47.4% males, mean age 49.94 ± 14.87 years) from Thrace, Greece, selected through a two-stage stratified sampling method. According to the Greek version of IPAQ, participants were classified as inactive/insufficiently active, sufficiently and highly active. Data on socio-demographic, lifestyle, and health-related variables were collected through structured interviews. Multivariate logistic regression analysis was performed to determine the independent effect of physical activity on subjects' characteristics using SPSS ver. 19. Half of the participants (49.8%) were inactive/insufficiently active, 418 participants (34.1%) were sufficiently active, and 198 participants (16.1%) were highly active. In univariate analysis, smoking ($p < 0.001$), higher coffee consumption ($p = 0.002$), higher adherence to Mediterranean diet ($p < 0.001$), napping during the day ($p = 0.017$) and short sleep duration ($p < 0.001$) were associated with lower prevalence of high activity. In adjusted analyses, sufficiently active participants had a lower risk for bad self-rated health (aOR = 0.63), hypertension (aOR = 0.41), dyslipidemia (aOR = 0.42), diabetes (aOR = 0.53), obesity (aOR = 0.61), cardiovascular diseases (aOR = 0.43), anxiety (aOR = 0.65), depression (aOR = 0.56), daily sleepiness (aOR = 0.62), poor sleep quality (aOR = 0.71), as well as for primary (aOR = 0.54) and secondary (aOR = 0.40) healthcare utilization compared to inactive participants. Higher-intensity physical activity did not enhance these beneficial

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effects of sufficient activity on subjects' characteristics. Physical inactivity significantly compromises health across multiple domains. Promoting even moderate-intensity physical activity may reduce chronic disease burden and healthcare utilization.

Keywords: physical activity; health status; healthcare utilization; lifestyle behaviors; mental health; chronic disease

1. Introduction

The relationship between physical activity and health outcomes has been extensively documented, establishing exercise as a fundamental pillar of preventive medicine [1,2]. Regular physical activity is consistently associated with a lower likelihood of acquiring long-term conditions such as diabetes, heart disease, specific cancer, high blood pressure, obesity, depression, and osteoporosis [3]. The World Health Organization (WHO) reports that noncommunicable diseases (NCDs) accounted for at least 43 million deaths worldwide in 2021 (18 million of which occurred before the age of 70 years), representing 75% of mortality not associated to pandemics. The majority of NCD deaths, or at least 19 million in 2021, are caused by cardiovascular illnesses, followed by cancers (10 million), chronic respiratory conditions (4 million), and diabetes (more than 2 million, including deaths from diabetic kidney disease). Moreover, NCDs are Europe's biggest health challenge, causing 80% of the burden and leading to 1.8 million avoidable premature deaths annually, with NCDs being major health concerns also in Greece, causing significant mortality and morbidity (with 50% of persons aged 15 years and over suffering from a chronic disease) [3]. Tobacco use, physical inactivity, the harmful use of alcohol, unhealthy diets and air pollution all increase the risk of dying from an NCD [3]. Therefore, promoting physical activity emerges as a critical strategy for public health initiatives aimed at disease prevention and health maintenance [4]. Despite the well-recognized health benefits, a significant proportion of the global population remains physically inactive [5], which highlights the urgent need for further research into the factors that facilitate or hinder physical activity engagement, as well as the varying effects of physical activity across different socio-demographic and cultural populations.

There is evidence demonstrating the substantive health benefits even of light-intensity physical activity (e.g., walking, light gardening, housework). The replacement of sedentary time with light physical activity reduces the risk of all-cause and cardiovascular disease mortality, improves blood pressure, cholesterol, insulin, and glucose levels, as well as body weight, and reduces the symptoms of depression and anxiety [6]. In 2020, the Canadian 24-Hour Movement Guidelines for Adults were the first to provide the recommendation that adults accumulate "several hours of light-intensity exercise, including standing" daily [7], based on the findings from the meta-analysis of Ekelund and colleagues, who observed that light-intensity physical activity was associated with a substantially reduced risk of mortality in a dose–response manner [8], and the meta-analysis of Chastin and colleagues who reported that doubling the time spent in light-intensity physical activity was associated with a 29% reduction in mortality [6]. However, recent meta-analyses confirm that higher-intensity or more frequent physical activity is associated with a reduced risk of cancer and all-cause mortality independent of time spent sedentary [9]. Moreover, the meta-analysis of Ku et al. observed that the risk of cardiovascular mortality was reduced by 20% for each 20 min increase in light-intensity physical activity [10], while the meta-analysis of Qiu et al. demonstrated that by comparison to participants who engaged in <3 h/day of light-intensity physical activity, all-cause mortality risk was reduced by 29%, 32%, and 44% for participants who engaged in 3–5 h/day, 5–7 h/day, and ≥7 h/day of light-intensity

physical activity, respectively [11]. All these findings indicate that all physical activity matters, including light-intensity physical activity, and more is better [11].

Roth et al. indicated that, between 1990 and 2013, death rates decreased in most nations, albeit to varying degrees; the USA, Japan, and Northern European countries had the most notable declines, with decline rates of 50–60% [12]. However, during the same time period, there were initial increases in the incidence of CVD in Greece and Eastern European countries, followed by relatively small reductions [13]. This is thought to be partly due to the Greek population's increased physical activity and decreased smoking prevalence [14]. Regarding physical activity, it is interesting to note that recent national research, conducted after 2013, suggests that fewer people are being inactive these days. In fact, more than half of Greeks are now getting involved in activities that are either moderately or vigorously intense [15,16]. The "Hellas Health" surveys also indicate a significant rise in how many Greek adults are quite active, going from 21.9% in 2006 to 31.7% in 2011. This increase was observed across most social and demographic groups, except for those in the highest socio-economic status [17]. Moreover, 52% of Greek individuals over the age of 15 engaged in activities of moderate intensity in 2014, according to Hellenic Statistical Authority (ELSTAT) [18]. Nonetheless, three out of four of them stated that they do not engage in any sports or fitness activities in their free time [18]. The ATTICA study, using a prospective representative sample of Greek adults residing in the area of Athens, demonstrated the protective effect of physical activity, particularly for men, in the prevention of CVD. In particular, active participants during the 10-year evaluation period exhibited a 0.51-fold reduced risk of developing CVD compared to those who reported a sedentary lifestyle [19].

Beyond its direct impact on physical and mental health, physical activity also exerts considerable influence on healthcare utilization. On the contrary, scientific evidence indicates convincingly, that physical inactivity not only is a serious hazard to health (increasing significantly the likelihood of chronic diseases as diabetes, hypertension, heart disease, stroke, and various cancers, having a negative impact on mental health, and bone density and being responsible for 9% of premature mortality), functional capacity and wellbeing, but has also been associated with increased healthcare costs (physical inactivity cost healthcare systems $53·8 billion worldwide in 2013), greater frequency of physician visits, and higher hospitalization rates [20,21]. Conversely, populations with higher activity levels tend to experience fewer hospital admissions and reduced overall healthcare expenditures, emphasizing the broader economic and systemic benefits of an active lifestyle [22].

To design and implement prevention strategies for chronic diseases, national or region-specific population representative baseline data on their prevalence and association with well-established risk factors are necessary. In the region of Thrace in Northern Greece, which is characterized by notable socio-cultural diversity, until recently, no study has ever been performed using such a large, randomly selected representative sample of the general population to record the prevalence of frequent chronic diseases and risk factors. Importantly, the study accounts for various socio-demographic factors (such as gender, age, marital status, cultural background, place of residence, education level, financial status, and employment status) and health behaviors (including smoking, alcohol and coffee consumption, adherence to the Mediterranean diet, daytime napping, and sleep duration) to provide a comprehensive and robust understanding of the observed associations. By analyzing data from this diverse cohort, the study seeks to deepen our understanding of how different levels and patterns of physical activity influence both individual health outcomes and broader healthcare demands. In this context, the present study aimed to explore the relationship between physical activity levels and a wide range of health characteristics—including self-rated health, symptoms of anxiety and depression, hypertension, dyslipidemia, diabetes mellitus, obesity, and sleep

difficulties—as well as patterns of healthcare utilization, such as visits to primary healthcare providers and hospital admissions.

2. Materials and Methods

2.1. Ethics

The study protocol was approved by the Democritus University Ethics Committee (Protocol Number 42570/294, Approval Date 5 March 2020) and adhered to the ethical principles of the Helsinki Declaration (1964 and its subsequent amendments). Participation was anonymous and voluntary. Written informed consent was obtained from all participants after they were provided with detailed information about the study's objectives and procedures.

2.2. Study Sample and Research Design

This cross-sectional study was conducted from April 2020 to February 2023 among adults residing in the region of Thrace, the northeastern prefecture of Greece. Thrace is notable for its cultural diversity, encompassing various national, ethnolinguistic, and religious groups, including:

(a) The indigenous Christian Orthodox population (65%),
(b) the Muslim minority, which represents about 30% of the population and includes the Pomaks and Roma-Gypsies, and
(c) the descendants of Armenian refugees and expatriated Greeks from the former Soviet Republics (approximately 5%).

A two-stage stratified sampling strategy was used. In the first stage, Thrace was divided into two strata based on urbanization levels: urban areas ($\geq$10,000 inhabitants) and semi-urban or rural areas (<10,000 inhabitants), according to the 2011 census. Approximately 40% of the population lived in urban settings. In the second stage, individuals were selected proportionally to the population size of each stratum through random telephone number generation based on area codes. After explaining the study's purpose, participants were invited to complete a structured questionnaire via a home interview conducted by trained researchers (pathologists, general practitioners and nurses). Each interview lasted approximately 30 min. No missing data were present. The following persons were excluded from this study: people aged < 18 years; persons living in institutions for chronically ill people; inmates of nursing homes and penitentiary establishments; homeless and migrants living in detention camps.

Based on the above described sampling procedure, 1800 inhabitants of Thrace were selected (700 from urban and 1100 from rural areas), out of which 110 were not included in the study due to the exclusion criteria (21 subjects were under 18 years old, 82 subjects were living in institutions for chronically ill people or nursing homes and 7 were living in detention camps). Out of the remaining 1690 subjects, 1227 subjects, 582 (47.4%) males and 645 (52.6%) females, with a mean age of 49.94 $\pm$ 14.87 years (range, 19–86 years; median age, 50 years) were included in the analysis (participation rate: 72.6%). The sampling scheme ensured that the study population was representative of the broader Thracian adult population.

Socio-Demographic Characteristics

Participants provided information on gender, age, marital status, cultural background, place of residence, educational attainment, employment status, and financial status. Education was categorized into three levels: low (basic education $\leq$ 9 years), medium (completion of high school or technical college), and high (university degree). Financial status was categorized based on the participants' net mean monthly household income over the past three years: low ($\leq$1000 Euro), medium (1001–2000 Euro), and high (>2000 Euro).

2.3. Assessment of Physical Activity

The International Physical Activity Questionnaire (IPAQ) is a frequently used instrument, suitable for the evaluation of population levels of self-reported physical activity [23]. The translated version of IPAQ, validated in the Greek population (IPAQ-Gr) by Papathanasiou et al. (2009), Ref. [24] was used to assess weekly energy expenditure. The IPAQ-Gr is a seven-item questionnaire with six questions that participants are asked to complete in order to record the number of days (frequency) and minutes per day (duration) that they participated in various types of walking, moderate and vigorous physical activities during the preceding seven days. A seventh question also measures how much time the participants spend sitting a typical workday. The IPAQ-Gr calculates a total physical activity score, expressed in MET-minutes per week (MET/min/wk^{-1}), by adding together walking, moderate, and vigorous physical activities. For the present analysis, participants were classified as inactive/insufficiently active, sufficiently active and highly active, according to the following IPAQ scoring guidelines [23]: "*sufficiently active, when either of the following three criteria were met: (a) 3 or more days of vigorous activity of at least 20 min per day, or (b) 5 or more days of moderate-intensity activity and/or walking of at least 30 min per day, or (c) 5 or more days of any combination of walking, moderate- intensity or vigorous-intensity activities achieving a minimum of at least 600 MET/min/wk^{-1}; highly active, when any of the following two criteria were met: (a) vigorous-intensity activity on at least 3 days accumulating a minimum of at least 1500 MET/min/wk^{-1}, or (b) 7 days of any combination of walking, moderate- or vigorous-intensity activities accumulating a minimum of at least 3000 MET/min/wk^{-1}. Finally, the third category was inactive/insufficiently active, when no activity was reported or some activity was reported but not enough to meet either of the other two categories.*"

2.4. Health and Lifestyle Indicators

Lifestyle and dietary habits were assessed as follows:

1. Smoking status and alcohol and caffeine consumption (number of drinks or cups per day).
2. Adherence to the Mediterranean diet was evaluated using the Mediterranean Diet Score (range: 0–55), with scores > 35 considered indicative of high adherence [25].
3. Daytime napping was recorded if naps exceeded 30 min.
4. Sleep duration was calculated using weighted averages between weekdays and weekends: (5/7 × weekday sleep duration) + (2/7 × weekend sleep duration). Participants were classified into three sleep duration categories: short (<6 h), normal (6–8 h), and long (>8 h) [26,27].

2.5. Health-Related Characteristics

Self-rated health, which was measured as participants' subjective answer to a single question: "How is your health in general?", was initially classified into five categories ("very bad," "bad," "fair," "good," "very good"), later dichotomized into "bad" (very bad, bad, fair) and "good" (good, very good) health status. Blood pressure was measured at participants' homes in the morning after five minutes of rest. Three seated readings were obtained at five-minute intervals using a mercury sphygmomanometer; the average of the second and third readings was used. Hypertension was defined as SBP $\geq$ 140 mmHg, DBP $\geq$ 90 mmHg, or the use of antihypertensive medication [28]. Diabetes mellitus (type 2) was identified based on self-reported medical diagnosis or use of antidiabetic medication [29,30]. Dyslipidemia was determined similarly [31,32]. Cardiovascular disease (CVD) was defined by a self-reported history of myocardial infarction, angina, bypass surgery, or stroke diagnosis [33].

2.6. Anthropometric Indices

Using standardized instruments and specifically developed standardized operating procedures, anthropometric measurements were collected by trained health professionals. Body height measured to the nearest 0.5 cm (using Measuring Rod: TANITA HEIGHT ROD; Tanita Corp., Tokyo, Japan) without shoes, while weight measured to the nearest 100 gr (using Digital portable certified scale: SECA MOD 877; Seca, Hamburg, Germany) without shoes and in light clothes. Body Mass Index (BMI) was calculated as weight (kg) divided by height squared (m^2), with obesity defined as BMI $\geq$ 30 kg/m^2 [34]. Waist circumference (WC), hip circumference (HC), and neck circumference (NC) were measured using a stretch-resistant tape following a standardized procedure [35,36]. The results were categorized as follows: high WC: >88 cm in women, >102 cm in men; high waist-to-hip ratio (WHR): >0.85 in women, >1.00 in men; high NC: >34 cm in women, >37 cm in men.

2.7. Mental Health Assessment

Anxiety was assessed using the Greek version of the original Zung Self-rating Anxiety Scale (SAS), a 20-item Likert scale. A raw score of $\geq$36 indicated clinically significant anxiety [37]. Depression was evaluated using the Greek version of the Beck Depression Inventory (BDI), a 21-item scale. A total score of $\geq$13 was used as the cut-off for significant depression [38–40].

2.8. Sleep Disturbances Assessment

Daytime sleepiness was assessed using the Greek version of the Epworth Sleepiness Scale (ESS), with scores > 10 indicating excessive sleepiness [41–43]. Insomnia was evaluated using the Athens Insomnia Scale (AIS), with scores > 5 indicating the presence of insomnia symptoms [44,45]. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI); poor sleep quality was defined by scores > 5 [46,47]. Obstructive Sleep Apnea (OSA) risk was screened with the Berlin Questionnaire (BQ); participants were considered at high risk if at least two of three categories were positive [48,49].

2.9. Healthcare Utilization

Healthcare utilization was assessed based on self-reported data. Primary healthcare utilization referred to visits to general practitioners, specialists, or medical doctors at private or public primary care facilities during the past month. Secondary healthcare utilization refers to hospital admissions within the past year.

2.10. Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics software, version 19.0 (IBM Corp., Armonk, NY, USA). Categorical variables were summarized as absolute and relative frequencies (%). The associations between physical activity levels and socio-demographic characteristics, health behaviors, health outcomes, and healthcare utilization were examined using chi-square tests. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to quantify associations. Multivariate logistic regression models (variable selection method: stepwise backward LR, with probability of removal set at 0.20) were used to identify independent predictors, adjusting for potential confounders: gender, age, marital status, cultural status, residence, education, financial status, employment status, smoking, alcohol and coffee consumption, Mediterranean diet adherence, daytime napping, and sleep duration. Correlation matrices and Hosmer-Lemeshow test indicated no multicollinearity and high accuracy for all regression models. Cronbach's alpha was used to assess the internal consistency of psychometric scales. All tests were two-tailed, and statistical significance was defined as $p \leq 0.05$.

3. Results

3.1. Subsection

Participants' socio-demographic characteristics are summarized in Table 1. Almost half of the participants (n = 611, 49.8%) were inactive/insufficiently active, 418 participants (34.1%) were sufficiently active, and 198 participants (16.1%) were highly active.

Table 1. Association of participants' physical activity with their socio-demographic characteristics.

	Total	Low	Medium	High	*p* Value
n	1227	611 (49.8)	418 (34.1)	198 (16.1)	
Sex					0.097
Females	645 (52.6)	320 (49.6)	233 (36.1)	92 (14.3)	
Males	582 (47.4)	291 (50.0)	185 (31.8)	106 (18.2)	
Age (years)					<0.001
≤40	337 (27.5)	126 (37.4)	119 (35.3)	92 (27.3)	
41–60	566 (46.1)	272 (48.1)	205 (36.2)	89 (15.7)	
>60	324 (26.4)	213 (65.7)	94 (29.0)	17 (5.2)	
Marital status					<0.001
Married	825 (67.2)	425 (51.5)	293 (35.5)	107 (13.0)	
Single	252 (20.5)	91 (36.1)	83 (32.9)	78 (31.0)	
Widowed	102 (8.3)	69 (67.6)	29 (28.4)	4 (3.9)	
Divorced	48 (3.9)	26 (54.2)	13 (27.1)	9 (18.8)	
Cultural status					<0.001
Greek Christians	807 (65.8)	378 (46.8)	272 (33.7)	156 (19.5)	
Greek Muslims	358 (29.2)	198 (55.3)	123 (34.4)	37 (10.3)	
Expatriated Greeks	62 (5.1)	35 (56.5)	23 (37.1)	4 (6.5)	
Place of residence					<0.001
Urban	524 (42.7)	202 (38.5)	192 (36.6)	130 (24.8)	
Rural	703 (57.3)	409 (58.2)	226 (32.1)	68 (9.7)	
Education level					<0.001
Low	406 (33.1)	252 (62.1)	137 (33.7)	17 (4.2)	
Medium	431 (35.1)	202 (46.9)	150 (34.8)	79 (18.3)	
High	390 (31.8)	157 (40.3)	131 (33.6)	102 (26.2)	
Financial status (n = 1052)					<0.001
Low	614 (58.4)	334 (54.4)	202 (32.9)	78 (12.7)	
Medium	258 (24.5)	135 (52.83	89 (34.5)	34 (13.2)	
High	180 (17.1)	60 (33.4)	60 (33.3)	60 (33.3)	
Working Status					<0.001
Government	499 (40.7)	279 (55.9)	106 (21.2)	114 (22.8)	
Manual worker	214 (17.4)	15 (7.0)	152 (71.0)	47 (22.0)	
Unemployed	106 (8.6)	59 (55.7)	36 (34.0)	11 (10.4)	
Student	40 (3.3)	9 (22.5)	11 (27.5)	20 (50.0)	
Retired	276 (22.5)	196 (71.0)	80 (29.0)	0 (0.0)	
Housework	92 (7.5)	53 (57.6)	33 (35.9)	6 (6.5)	

Note. Data were expressed as the number of subjects (percentage, %).

3.2. Physical Activity and Socio-Demographic Characteristics

The majority of the participants were married (67.2%), only 8.6% were unemployed, and their educational level was almost equally distributed into three levels (low 33.1%, medium 35.1% and high 31.8%). More than half of the households were placed in rural

settings (57.3%). Most of the participants belonged to the lower income level (614 subjects, 58.4%), 258 participants (24.5%) belonged to the medium, and 180 participants (17.1%) belonged to the higher income level. Regarding cultural status, 65.8% were Greek Christians, 29.2% were Greek Muslims, and 5.1% were expatriated Greeks. The association of physical activity with these socio-demographic characteristics is displayed in Table 1. High physical activity was more frequent among younger ages ($p < 0.001$), unmarried or divorced subjects ($p < 0.001$), Greek Christians ($p < 0.001$), inhabitants of urban areas ($p < 0.001$), subjects of high financial status ($p < 0.001$), students, government or manual workers ($p < 0.001$), while it was positively associated with education ($p < 0.001$); a tendency towards higher frequency of high physical activity was observed in males ($p = 0.097$).

3.3. Physical Activity and Lifestyle Habits

As shown in Table 2, regarding lifestyle and other habits, 34.1% of the sample were current smokers, 23.6% had high alcohol consumption (≥4 glasses/week), and 31.9% had high coffee consumption (≥3 cups/day). The majority of participants reported low adherence to the Mediterranean diet (78.9%), and more than half of the study population used to take a nap during the day for more than 30 min (57.6%). Based on participants' self-reported sleep duration, the prevalence of short and long sleep duration was 22.2% and 14.2%, respectively. High physical activity was more frequent among non-smokers ($p < 0.001$), subjects with low adherence to the Mediterranean diet ($p < 0.001$), those who do not take long (>30 min) naps during the day ($p = 0.017$), while it was negatively associated with coffee consumption ($p = 0.002$), and positively associated with nocturnal sleep duration ($p < 0.001$).

Table 2. Association of subjects' physical activity with lifestyle characteristics.

	Total	Low	Medium	High	*p* Value
Life habit factors					
Smoking					<0.001
Never smoking	474 (38.6)	223 (47.0)	131 (27.6)	120 (25.3)	
Ex-smoking	334 (27.2)	183 (54.8)	107 (32.0)	44 (13.2)	
Current smoking	419 (34.1)	205 (48.9)	180 (43.0)	34 (8.1)	
Alcohol consumption					0.086
None	621 (50.6)	319 (51.4)	200 (32.2)	102 (16.4)	
1–3 glasses/week	316 (25.8)	143 (45.3)	113 (35.8)	60 (19.0)	
4–6 glasses/week	215 (17.5)	106 (49.3)	77 (35.8)	32 (14.9)	
>6 glasses/week	75 (6.1)	43 (57.3)	28 (37.3)	4 (5.3)	
Coffee consumption					0.002
None	113 (9.2)	47 (41.6)	36 (31.9)	30 (26.5)	
1–2 cups/day	723 (58.9)	351 (48.5)	257 (35.5)	115 (15.9)	
3–4 cups/day	320 (26.1)	171 (53.4)	98 (30.6)	51 (15.9)	
>4 cups/day	71 (5.8)	42 (59.2)	27 (38.0)	2 (2.8)	
Adherence to MED diet					<0.001
Low	968 (78.9)	465 (48.0)	326 (33.7)	177 (18.3)	
High	259 (21.1)	146 (56.4)	92 (35.5)	21 (8.1)	
Nap during the day					0.017
No	520 (42.4)	250 (48.1)	168 (32.3)	102 (19.6)	
Yes	707 (57.6)	361 (51.1)	250 (35.4)	96 (13.6)	

Table 2. *Cont.*

	Total	Low	Medium	High	*p* Value
Sleep duration					<0.001
Short	273 (22.2)	182 (66.7)	80 (29.3)	11 (4.0)	
Normal	780 (63.6)	358 (45.9)	276 (35.4)	146 (18.7)	
Long	174 (14.2)	71 (40.8)	62 (35.6)	41 (23.6)	

Note. MED diet = Mediterranean diet.

3.4. Independent Determinants of Physical Activity

Significant independent determinants of high physical activity (with a percentage of correct classification of 84.8%) obtained by multivariate logistic regression analysis are shown in Table 3. Males (aOR = 1.67), subjects aged ≤40 (aOR = 4.29) or aged 41–60 years old (aOR = 2.04), those with medium (aOR = 5.49) or high (aOR = 5.98) education level, and those with normal (aOR = 2.46) or long (aOR = 4.80) sleep duration had higher odds of having a high physical activity level. Subjects with low (aOR = 0.33) or medium (aOR = 0.49) financial status, ex- (aOR = 0.46) or current (aOR = 0.25) smokers, those with high adherence to the Mediterranean diet (aOR = 0.48), and those who used to take a nap during the day for more than 30 min (aOR = 0.66) had lower odds of achieving a high physical activity level.

Table 3. Significant determinants of high physical activity were obtained by a multivariate logistic regression model.

	aOR	95% CI	*p* Value
Sex			
Females	Ref.		
Males	1.67	1.16–2.41	0.006
Age (years)			
≤40	4.29	2.29–8.03	<0.001
41–60	2.04	1.11–3.74	0.022
>60	Ref.		
Cultural status			
Greek Christians	Ref.		
Greek Muslims	1.39	0.76–2.57	0.290
Expatriated Greeks	0.31	0.10–0.97	0.045
Education level			
Low	Ref.		
Medium	5.49	2.68–11.22	<0.001
High	5.98	2.70–13.25	<0.001
Financial status			
Low	0.33	0.19–0.56	<0.001
Medium	0.49	0.29–0.83	0.009
High	Ref.		
Smoking			
Never smoking	Ref.		
Ex-smoking	0.46	0.30–0.72	0.001
Current smoking	0.25	0.16–0.39	<0.001
Adherence to MED diet			
Low	Ref.		
High	0.48	0.29–0.82	0.007

Table 3. *Cont.*

	aOR	95% CI	*p* Value
Nap during the day			
No	Ref.		
Yes	0.66	0.46–0.95	0.027
Sleep duration			
Short	Ref.		
Normal	2.46	1.25–4.85	0.009
Long	4.80	2.20–10.50	<0.001

Note. aOR = Adjusted odds ratio; CI = Confidence interval; All subjects' sociodemographic characteristics (sex, age, marital status, cultural status, place of residence, education level, financial status, working status), and lifestyle habits (smoking status, alcohol consumption, daily coffee consumption, adherence to the Mediterranean diet, nap during the day, sleep duration) were included in the model.

3.5. Physical Activity and Health-Related Characteristics

Regarding the self-reported health indices, 295 participants (24.0%) reported bad health (Table 4). In the univariate statistical analysis, physical activity was strongly associated with self-reported health ($p < 0.001$); bad health was reported by 31.4%, 21.8%, and 6.1% of the insufficiently active, sufficiently active, and highly active participants, respectively, which indicates significant reductions of the likelihood of bad health by 39% and 86% in sufficiently active, and highly active participants (Table 5). This negative association between physical activity and self-reported health remained in the multivariate analysis even after adjusting for all possible confounders; in particular, sufficiently active (aOR = 0.63, $p = 0.011$) and highly active (aOR = 0.29, $p = 0.025$) participants were less likely to report bad health compared to insufficiently active participants (Table 6). Moreover, highly active participants were even less likely to report bad health compared to sufficiently active participants (aOR = 0.46, $p = 0.025$) (Figures 1–3).

Table 4. Association of subjects' physical activity with health characteristics and healthcare utilization.

	Total	Low	Medium	High	*p* Value
Health characteristics					
Bad self-rated health	295 (24.0)	192 (31.4)	91 (21.8)	12 (6.1)	<0.001
Cardiovascular risk factors					
Hypertension	431 (35.1)	289 (47.3)	103 (24.6)	39 (19.7)	<0.001
Dyslipidemia	397 (32.4)	278 (45.5)	97 (23.2)	22 (11.1)	<0.001
Diabetes mellitus	117 (9.5)	82 (13.4)	29 (6.9)	6 (3.0)	<0.001
Anthropometric indices					
Obesity	460 (37.5)	285 (46.6)	142 (34.0)	33 (16.7)	<0.001
High waist circumference	744 (60.6)	422 (69.1)	264 (63.2)	58 (29.3)	<0.001
High waist-to-hip ratio	765 (62.6)	399 (65.8)	282 (67.5)	84 (42.4)	<0.001
High neck circumference	611 (49.8)	349 (57.1)	223 (53.3)	39 (19.7)	<0.001
Cardiovascular disease					
Total	121 (9.9)	85 (13.9)	20 (4.8)	16 (8.1)	<0.001
Males	62 (10.7)	44 (15.1)	9 (4.9)	9 (8.5)	0.001
Females	59 (9.1)	41 (12.8)	11 (4.7)	7 (7.6)	0.004
Psychological status					
Anxiety symptoms	414 (33.7)	239 (39.1)	116 (27.8)	59 (29.8)	<0.001
Depression symptoms	352 (28.7)	222 (36.3)	99 (23.7)	31 (15.7)	<0.001

Table 4. *Cont.*

	Total	Low	Medium	High	*p* Value
Sleep disorders					
Excessive day sleepiness	120 (9.8)	73 (11.9)	30 (7.2)	17 (8.6)	0.034
Insomnia	230 (18.7)	140 (22.9)	69 (16.5)	21 (10.6)	<0.001
Poor sleep quality	473 (38.5)	284 (46.5)	150 (35.9)	39 (19.7)	<0.001
High risk for OSA	424 (34.6)	254 (41.6)	136 (32.5)	34 (17.2)	<0.001
Healthcare utilization					
Primary healthcare utilization	551 (44.9)	326 (53.4)	158 (37.8)	67 (33.8)	<0.001
Hospitalization	153 (12.5)	105 (17.2)	31 (7.4)	17 (8.6)	<0.001

Note. Data were expressed as the number of subjects (percentage, %).

Table 5. Association of subjects' physical activity with their health characteristics and healthcare utilization expressed as crude odds ratios (cOR) with their 95% confidence interval (CI) obtained by means of simple logistic regression models. *Italics* denote the reference category.

	Medium vs. *Low*	*p* Value	High vs. *Low*	*p* Value	High vs. *Medium*	*p* Value
Health characteristics						
Bad self-rated health	0.61 (0.46–0.81)	0.001	0.14 (0.08–0.26)	<0.001	0.23 (0.12–0.44)	<0.001
Cardiovascular risk factors						
Hypertension	0.36 (0.28–0.48)	<0.001	0.27 (0.19–0.40)	<0.001	0.75 (0.50–1.14)	0.174
Dyslipidemia	0.36 (0.27–0.48)	<0.001	0.15 (0.09–0.24)	<0.001	0.41 (0.25–0.68)	0.001
Diabetes mellitus	0.48 (0.31–0.75)	0.001	0.20 (0.09–0.47)	<0.001	0.42 (0.17–1.03)	0.057
Anthropometric indices						
Obesity	0.59 (0.46–0.76)	<0.001	0.23 (0.15–0.34)	<0.001	0.39 (0.25–0.60)	<0.001
High waist circumference	0.77 (0.59–0.99)	0.049	0.19 (0.13–0.26)	<0.001	0.24 (0.17–0.35)	<0.001
High waist-to-hip ratio	1.08 (0.83–1.40)	0.589	0.38 (0.28–0.53)	<0.001	0.36 (0.25–0.50)	<0.001
High neck circumference	0.86 (0.67–1.10)	0.232	0.18 (0.13–0.27)	<0.001	0.21 (0.14–0.32)	<0.001
Cardiovascular disease						
Total	0.31 (0.19–0.52)	<0.001	0.54 (0.31–0.95)	0.033	1.75 (0.89–3.46)	0.107
Males	0.28 (0.14–0.60)	0.001	0.52 (0.25–1.11)	0.090	1.81 (0.70–4.72)	0.222
Females	0.34 (0.17–0.67)	0.002	0.56 (0.24–1.30)	0.175	1.66 (0.62–4.43)	0.310
Psychological status						
Anxiety	0.60 (0.46–0.78)	<0.001	0.66 (0.47–0.93)	0.019	1.11 (0.76–1.60)	0.599
Depression	0.54 (0.41–0.72)	<0.001	0.33 (0.21–0.49)	<0.001	0.60 (0.38–0.93)	0.024
Sleep disorders						
Excessive day sleepiness	0.57 (0.37–0.89)	0.013	0.69 (0.40–1.21)	0.193	1.22 (0.65–2.26)	0.539
Insomnia	0.67 (0.48–0.92)	0.012	0.40 (0.25–0.65)	<0.001	0.60 (0.36–1.01)	0.055
Poor sleep quality	0.64 (0.50–0.83)	0.001	0.28 (0.19–0.42)	<0.001	0.44 (0.29–0.66)	<0.001
High risk for OSA	0.68 (0.52–0.88)	0.003	0.29 (0.20–0.44)	<0.001	0.43 (0.28–0.66)	<0.001
Healthcare utilization						
Primary healthcare utilization	0.53 (0.41–0.69)	<0.001	0.45 (0.32–0.63)	<0.001	0.84 (0.59–1.20)	0.341
Hospitalization	0.39 (0.25–0.59)	<0.001	0.45 (0.26–0.78)	0.004	1.17 (0.63–2.17)	0.613

Note. OSA = obstructive sleep apnea.

Table 6. Association of subjects' physical activity with their health characteristics and healthcare utilization expressed as adjusted odds ratios (aOR) with their 95% confidence interval (CI) obtained by means of multiple logistic regression models adjusted for socio-demographic characteristics and lifestyle habits. *Italics* denote the reference category.

	Physical Activity					
	Medium vs. *Low*	***p* Value**	**High vs. *Low***	***p* Value**	**High vs. *Medium***	***p* Value**
Health characteristics						
Bad self-rated health	0.63 (0.44–0.90)	0.011	0.29 (0.14–0.60)	0.001	0.46 (0.24–0.91)	0.025
Cardiovascular risk factors						
Hypertension	0.41 (0.30–0.57)	<0.001	0.74 (0.47–1.17)	0.197	1.55 (0.91–3.05)	0.105
Dyslipidemia	0.42 (0.31–0.58)	<0.001	0.34 (0.20–0.59)	<0.001	0.67 (0.36–1.24)	0.206
Diabetes mellitus	0.53 (0.33–0.86)	0.010	0.35 (0.14–0.92)	0.033	0.64 (0.22–1.89)	0.423
Anthropometric indices						
Obesity	0.61 (0.45–0.83)	0.001	0. 39 (0.24–0.85)	<0.001	0.71 (0.42–1.20)	0.203
High waist circumference	0.84 (0.64–1.11)	0.227	0.25 (0.17–0.37)	<0.001	0.30 (0.20–0.45)	<0.001
High waist-to-hip ratio	1.11 (0.82–1.51)	0.492	0.58 (0.39–0.87)	0.008	0.52 (0.35–0.79)	0.002
High neck circumference	0.85 (0.66–1.12)	0.267	0.20 (0.13–0.31)	<0.001	0.24 (0.15–0.36)	<0.001
Cardiovascular disease						
Total	0.43 (0.26–0.71)	0.001	0.65 (0.29–1.49)	0.312	1.23 (0.43–3.49)	0.701
Males	0.30 (0.14–0.64)	0.002	0.61 (0.16–2.42)	0.483	1.89 (0.27–13.12)	0.519
Females	0.58 (0.28–1.22)	0.150	0.93 (0.27–3.24)	0.907	1.51 (0.37–6.11)	0.563
Psychological status						
Anxiety	0.65 (0.48–0.87)	0.004	1.11 (0.74–1.67)	0.610	1.42 (0.96–2.11)	0.079
Depression	0.56 (0.41–0.75)	<0.001	0.47 (0.30–0.74)	0.001	0.87 (0.53–1.46)	0.605
Sleep disorders						
Excessive day sleepiness	0.62 (0.39–0.98)	0.043	0.82 (0.43–1.54)	0.535	1.46 (0.69–3.08)	0.325
Insomnia	0.78 (0.56–1.09)	0.144	0.51 (0.30–0.87)	0.014	0.63 (0.35–1.16)	0.141
Poor sleep quality	0.71 (0.54–0.93)	0.013	0.35 (0.23–0.54)	<0.001	0.45 (0.28–0.72)	0.001
High risk for OSA	0.85 (0.63–1.15)	0.292	0.58 (0.36–0.94)	0.026	0.68 (0.39–1.18)	0.166
Healthcare utilization						
Primary healthcare utilization	0.54 (0.42–0.70)	<0.001	0.49 (0.34–0.71)	<0.001	0.79 (0.52–1.19)	0.251
Hospitalization	0.40 (0.26–0.61)	<0.001	0.41 (0.23–0.74)	0.003	0.99 (0.47–2.09)	0.987

Note. OSA = obstructive sleep apnea.

Among the entire cohort, the prevalence of hypertension was 35.1%, dyslipidemia was 32.4%, and diabetes was 9.5%. The association between physical activity and cardiovascular risk factor profile is shown in Tables 4–6 and Figures 1–3. Insufficiently active participants had the highest prevalence of hypertension (47.3%), dyslipidemia (45.5%), and diabetes (13.4%). Higher physical activity was associated with a gradual reduction in hypertension ($p < 0.001$), dyslipidemia ($p < 0.001$), and diabetes ($p < 0.001$) (Table 4). Multivariate statistical analysis, controlling for the effect of all possible confounders, revealed that sufficiently active participants were 59% less likely to have hypertension ($p < 0.001$), 58% less likely to have dyslipidemia ($p < 0.001$), and 47% less likely to have diabetes ($p = 0.010$) compared to insufficiently active participants (Table 6). Moreover, highly active participants had an even lower risk for dyslipidemia (by 66%, $p < 0.001$) and diabetes (by 65%, $p = 0.033$) but not for hypertension ($p = 0.197$), compared to insufficiently active participants. However,

the differences between sufficiently active and highly active participants in the risk of hypertension (p = 0.105), dyslipidemia (p = 0.206), and diabetes (p = 0.423) were not statistically significant (Table 6).

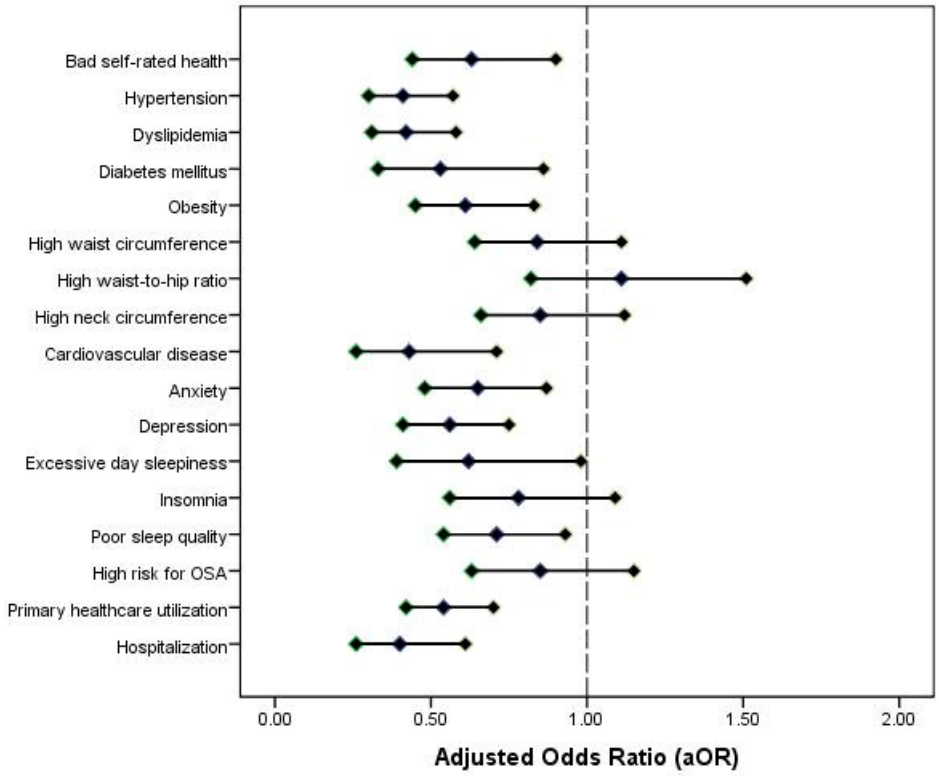


Figure 1. The association of medium physical activity with subjects' health characteristics and healthcare utilization in relation to low (=reference category) physical activity expressed as adjusted odds ratios (aOR) with their 95% confidence interval (CI) obtained by means of multiple logistic regression models adjusted for socio-demographic characteristics and lifestyle habits.

The prevalence of cardiovascular diseases was 9.9% (10.7% in males and 9.1% in females). The association between physical activity and cardiovascular diseases is shown in Tables 4–6. The highest prevalence (13.9%) of cardiovascular diseases was observed among insufficiently active participants (15.1% in males and 12.8% in females), while the lowest prevalence (4.8%) was observed among sufficiently active participants (4.9% in males and 4.7% in females) (Table 4). In univariate statistical analysis, sufficient physical activity was associated with a statistically significant lower likelihood of cardiovascular disease in the total sample by 69% (cOR = 0.31, $p < 0.001$), in males by 72% (cOR = 0.28, p = 0.001), and in females by 66% (cOR = 0.34, p = 0.002). However, in multivariate statistical analysis, controlling for the effect of all possible confounders, the association of sufficient physical activity with cardiovascular diseases persisted in the total sample (aOR = 0.43, p = 0.001), and in males (aOR = 0.30, p = 0.002), but not in females; although sufficiently active female participants were 42% less likely to have cardiovascular diseases, this relation did not reach the statistical significance (p = 0.150). The association of high physical activity with cardiovascular disease was not statistically significant (p = 0.312 in the total sample; p = 0.483 in males; p = 0.907 in females) (Figures 1–3).

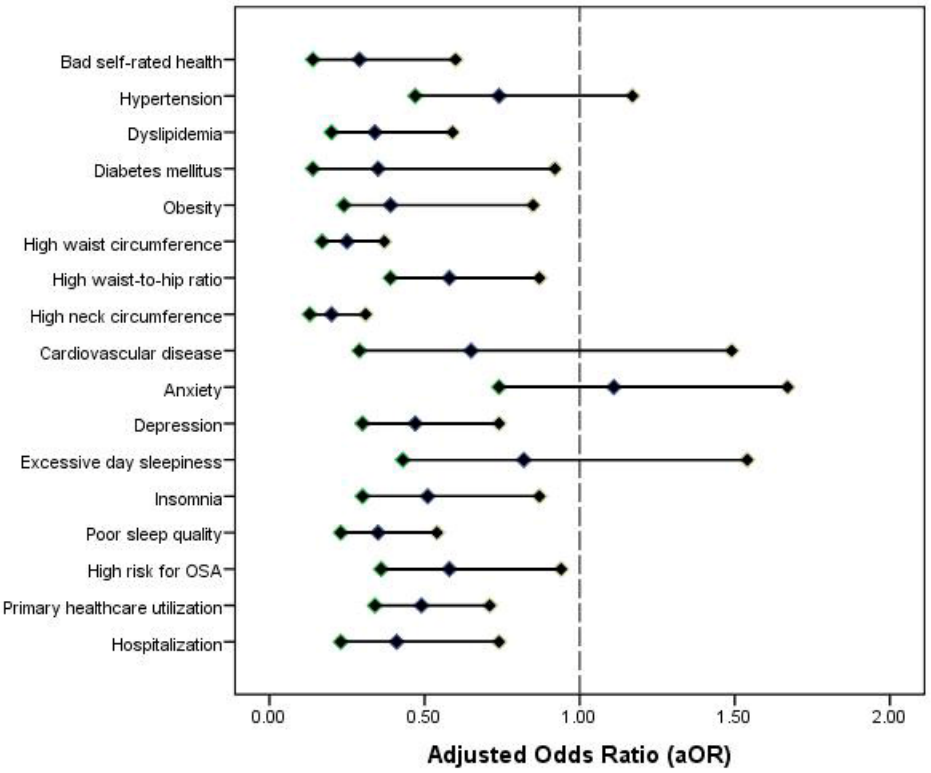


Figure 2. The association of high physical activity with subjects' health characteristics and healthcare utilization in relation to low (=reference category) physical activity expressed as adjusted odds ratios (aOR) with their 95% confidence interval (CI) obtained by means of multiple logistic regression models adjusted for socio-demographic characteristics and lifestyle habits.

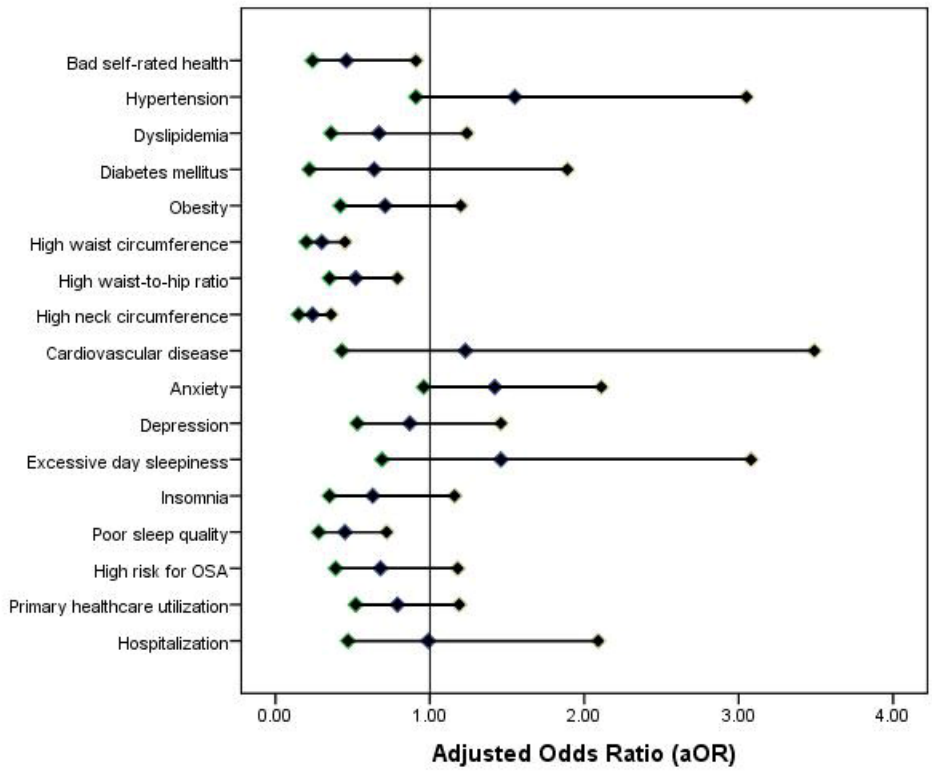


Figure 3. The association of high physical activity with subjects' health characteristics and healthcare utilization in relation to medium (=reference category) physical activity expressed as adjusted odds ratios (aOR) with their 95% confidence interval (CI) obtained by means of multiple logistic regression models adjusted for socio-demographic characteristics and lifestyle habits.

3.6. Physical Activity and Anthropometric Indices

Among the entire cohort, the prevalence of obesity was 37.5%, high waist circumference was 60.6%, high waist-to-hip ratio was 62.6%, and high neck circumference was 49.8%. The association between physical activity and anthropometric indices is shown in Tables 4–6. An increase in physical activity was associated with a gradual decrease in obesity ($p < 0.001$), while high waist circumference, waist-to-hip ratio, and neck circumference were less frequent in highly active participants (all $p < 0.001$) (Table 4).

Multivariate statistical analysis, controlling for the effect of all possible confounders, revealed that sufficiently active (aOR = 0.61, $p = 0.001$) and highly active (aOR = 0.39, $p < 0.001$) participants were less likely to be obese compared to insufficiently active participants; the risk of obesity was similar ($p = 0.203$) between sufficiently and highly active participants. In adjusted analyses, only high physical activity was associated with lower odds of high waist circumference (aOR = 0.25, $p < 0.001$; aOR = 0.30, $p < 0.001$), waist-to-hip ratio (aOR = 0.58, $p = 0.008$; aOR = 0.52, $p = 0.002$), and neck circumference (aOR = 0.20, $p < 0.001$; aOR = 0.24, $p < 0.001$) compared to insufficiently and sufficiently active participants; the risk of high waist circumference, waist-to-hip ratio, and neck circumference was similar ($p = 0.203$) between insufficiently and sufficiently active participants ($p = 0.227$, $p = 0.492$, and $p = 0.267$, respectively) (Table 6; Figures 1–3).

3.7. Physical Activity and Mental Health

The internal consistency of the Zung self-rating Anxiety Scale and Beck Depression Inventory (BDI) was very high (Cronbach's α coefficient was 0.83 and 0.88, respectively). The prevalence of anxiety was 33.7% and the prevalence of depression was 28.7%. Overall, both anxiety ($p < 0.001$) and depression ($p < 0.001$) were significantly associated with physical activity (Tables 4–6; Figures 1–3). The highest prevalence of anxiety (39.1%) and depression (36.3%) was observed among inactive subjects. The lowest prevalence of anxiety (27.8%) was observed in subjects with moderate physical activity, while the prevalence of depression decreased as physical activity increased. Multivariate analysis adjusting for the effect of subjects' characteristics, revealed that moderate physical activity was associated with a lower likelihood of anxiety (aOR = 0.65, $p = 0.004$; aOR = 0.62, 95% CI = 0.42–0.92, $p = 0.016$ in females; aOR = 0.54, 95% CI = 0.35–0.85, $p = 0.007$ in males) and depression (aOR = 0.56, $p < 0.001$; aOR = 0.58, 95% CI = 0.36–0.93, $p = 0.022$ in females; aOR = 0.60, 95% CI = 0.37–0.97, $p = 0.039$ in males). High physical activity was associated with an even lower likelihood of depression (aOR = 0.47, $p = 0.001$; aOR = 0.54, 95% CI = 0.34–0.87, $p = 0.011$ in females; aOR = 0.43, 95% CI = 0.22–0.84, $p = 0.015$ in males), but not of anxiety (aOR = 1.11, $p = 0.610$; aOR = 1.16, 95% CI = 0.67–2.02, $p = 0.593$ in females; aOR = 0.89, 95% CI = 0.38–2.11, $p = 0.803$ in males) compared to inactive subjects.

3.8. Physical Activity and Sleep Disorders

According to the Greek versions of the Epworth sleepiness scale (ESS), Athens insomnia scale (AIS), Pittsburgh sleep quality index (PSQI), and Berlin questionnaire (BQ), the prevalence of daytime sleepiness was 9.8%, of insomnia 18.7%, of poor sleep quality 38.5% and of high risk of obstructive sleep apnea 34.6%. The internal consistency of all four questionnaires was very high (Cronbach's α coefficient ranged from 0.77 to 0.89). The association of physical activity with sleep disorders is shown in Tables 4–6 and Figures 1–3. The prevalence of sleep disorders decreased with increasing physical activity levels (daytime sleepiness: $p = 0.034$; insomnia: $p < 0.001$; poor sleep quality: $p < 0.001$; risk of obstructive sleep apnea: $p < 0.001$). The associations of physical activity with sleep disorders remained statistically significant even after adjustment for subjects' characteristics; in particular, sufficient physical activity was associated with 38% lower odds of excessive day sleepiness

(aOR = 0.62, $p = 0.043$), and high physical activity was associated with 49% lower odds of insomnia (aOR = 0.51, $p = 0.014$), with 65% lower odds of poor sleep quality (aOR = 0.35, $p < 0.001$) and with 42% lower odds of high risk of obstructive sleep apnea (aOR = 0.58, $p = 0.026$).

3.9. Physical Activity and Healthcare Utilization

Regarding the utilization of primary and secondary healthcare, 44.9% of the sample population utilized primary healthcare during the past month, and 12.5% reported having been admitted to a hospital in the past year. The association between physical activity and healthcare utilization is shown in Tables 4–6 and Figures 1–3. Insufficiently active participants (primary healthcare: 53.4%; secondary healthcare: 17.2%) use health services more often than sufficiently active (primary healthcare: 38.8%; secondary healthcare: 7.4%), and highly active (primary healthcare: 33.8%; secondary healthcare: 8.6%) participants ($p < 0.001$). After adjustment for all possible confounders, it was found that sufficiently active and highly active participants were about 50% less likely to use primary healthcare services (sufficiently active: aOR = 0.54, $p < 0.001$; highly active: aOR = 0.49, $p < 0.001$) and 60% less likely to be hospitalized (sufficiently active: aOR = 0.40, $p < 0.001$; highly active: aOR = 0.41, $p < 0.001$), compared to insufficiently active participants.

4. Discussion

This study underscores the significant positive impact of physical activity on a wide range of self-reported health indicators among a diverse adult population in Northern Greece. The findings align with a growing body of evidence demonstrating the broad benefits of physical activity on diverse health outcomes and healthcare utilization patterns, further reinforcing its critical role in promoting overall well-being and reducing healthcare burdens.

Mechanistically, higher physical activity likely amplifies skeletal muscle energy-sensing pathways—AMPK and SIRT1—that co-activate PGC-1α and downstream transcriptional programs (NRF1/2, TFAM) to expand mitochondrial content and oxidative capacity. Repeated exposure (greater intensity/volume) yields larger, more durable transcriptional and proteomic adaptations across tissues, as shown in multi-omic endurance-training datasets and narrative syntheses, and is consistent with the graded associations we observed for hypertension, dyslipidemia, diabetes, and obesity [50–52].

Consistent with prior research [2,4], our results demonstrate that higher levels of physical activity are strongly associated with better self-rated health, lower prevalence of chronic conditions such as hypertension, dyslipidemia, and obesity, and improved mental health outcomes. These associations persisted even after adjusting for a comprehensive set of socio-demographic and behavioral confounders, highlighting the independent and protective role of physical activity. Specifically, our observation that physically active participants exhibited lower rates of cardiovascular disease supports existing evidence regarding the cardioprotective effects of regular exercise [28,53,54]. This may be attributed to multiple mechanisms, including improvements in endothelial function, reductions in systemic inflammation, enhanced lipid profiles, and better blood pressure regulation [55]. Moreover, the beneficial influence of physical activity on mental health, evidenced by lower anxiety and depression scores among active individuals, reinforces the hypothesis that exercise acts not only through physiological pathways but also via neurochemical and psychosocial mechanisms, such as increased endorphin production, stress buffering, and improved social engagement [39,56].

Vascular benefits with greater activity may be mediated by exercise-induced shear stress, which enhances endothelial eNOS Ser1177 phosphorylation and NO bioavailability,

improving vasomotor function and blood pressure regulation. Human conduit-artery studies and mechanistic reviews indicate these signaling events scale with the shear stimulus, offering a biological basis for stronger associations at higher activity levels [57–59].

Our findings regarding anthropometric indices further validate the critical role of physical activity in the prevention and management of obesity. The inverse association between physical activity and markers of central adiposity, such as waist circumference, waist-to-hip ratio, and neck circumference, is particularly noteworthy given the strong link between visceral fat and increased risk for metabolic syndrome, cardiovascular events, and certain cancers [34,60–64].

Beyond energy balance, inter-organ signaling likely contributes to the more favorable adiposity profile among highly active participants. Exercise-induced myokines, notably irisin (FNDC5), can promote browning of white adipose tissue through PGC-1α/PRDM16/UCP1 pathways, increasing thermogenic capacity and lipid oxidation; while magnitudes in humans vary by depot, sex, and training protocol, higher training loads elicit greater endocrine responses [65–67].

Neurobiological mechanisms may also underlie the lower odds of anxiety and depression. Exercise increases cerebral BDNF, facilitating neurogenesis and synaptic plasticity; in parallel, skeletal muscle PGC-1α1 upregulates kynurenine aminotransferases, diverting circulating kynurenine to kynurenic acid, which cannot cross the blood–brain barrier—thus buffering stress-related neurotoxic signaling. These pathways plausibly exhibit dose–response behavior, aligning with stronger associations at higher activity levels [68–70].

Importantly, beyond individual-level benefits, the association between higher physical activity levels and reduced primary and secondary healthcare utilization has significant implications at the population level. Reduced healthcare use among active individuals implies that promoting physical activity could substantially alleviate the financial burden on national healthcare systems, improve service delivery efficiency, and enhance quality of life at a societal scale [20,22].

The compelling body of recent literature overwhelmingly reinforces that the societal value of promoting physical activity extends far beyond the direct reduction in disease risk and mortality. On a macro level, physical activity has been firmly established as a determinant of a healthy life and overall personal happiness at a population level across various regions [71]. The effectiveness of physical activity is rooted in its ability to target both central nervous system influences on behavior (such as appetite, mood, and cognitive functions) and peripheral metabolic pathways (including thermogenesis in adipose tissue and the regulation of key metabolic organs like skeletal muscle and the liver) [64].

A critical area of focus is the fight against overweight and obesity, which are major global problems [61]. Recent work confirms that central adiposity is a powerful predictor of cardiometabolic risk, with markers like the waist-to-height ratio being closely linked to conditions such as elevated blood pressure, dyslipidemia, and increased glycemia [60,63]. Mechanistically, this central adiposity, typically measured by waist circumference, correlates with the presence of pro-inflammatory adipokines, driving the systemic inflammation that underlies complications like Diabetic Retinopathy in Type 2 Diabetes (T2D) patients [62]. For effective weight management, studies consistently show that combined diet and physical activity interventions yield superior health outcomes compared to either component alone [61].

The benefits of regular exercise extend to even the most vulnerable and high-risk populations. In adult patients with Congenital Heart Disease (CHD), for example, regular exercise has been proven to improve functional capacity and quality of life while reducing cardiovascular event risk, contrasting sharply with the negative consequences of physical inactivity [55]. Furthermore, in socio-economically disadvantaged groups, such as those in

the Basic Livelihood Security Program, poor chronic disease outcomes—specifically the incidence of hypertension and dyslipidemia—are strongly related to low physical activity and poor eating habits, emphasizing the importance of simple, accessible physical activity like walking [54].

Beyond clinical metrics, physical activity is a potent psychological buffer. Among university students, exercise has been shown to mitigate the risk of anxiety, depression, and stress, particularly protecting against the high pressures of academic life [58]. This protective effect is similarly observed in occupational settings, where specialized Physical Activity-Led Workplace Health Promotion Interventions have proven effective in increasing employee activity levels and reducing psychological stress [72].

For a successful public health policy, the implementation and economic arguments must be addressed. Studies have quantified significant financial benefits, demonstrating that promoting physical activity in high-risk patients with Diabetes Mellitus leads to quantifiable reductions in both direct and indirect healthcare costs [73]. Moreover, for previously non-compliant patients, the continuation of Physical Activity on Prescription has been found to be a cost-effective intervention, provided adherence-mediating factors are addressed [74]. Finally, the success of community-based programs, such as peer-led walking interventions targeting inactive older adults in disadvantaged communities, has been shown to be both effective and cost-effective in promoting activity and addressing health inequalities [75]. These findings underscore the crucial role of the built environment, as satisfaction with factors like safety levels and the availability of natural environments and public transportation are shown to significantly influence local community physical activity levels and self-rated health [53].

Higher activity is consistent with enhanced glucose transport via contraction-induced AMPK $\rightarrow$ AS160 signaling and training-related increases in GLUT4 content, together improving insulin sensitivity. Concurrent anti-inflammatory re-programming (reductions in basal CRP/TNF-α/IL-6) and Nrf2-mediated antioxidant defenses likely contribute to the broad risk reductions and lower healthcare utilization observed in more active individuals [76–79].

Our findings are consistent with evidence from other Mediterranean populations. In Spain, national analyses from the 2017 Encuesta Nacional de Salud (ENSE) showed that adults with higher physical activity levels had lower hospitalization prevalence and fewer emergency department visits, supporting our observation that more active individuals use health services less frequently [80]. A large Spanish population-based prospective study also reported that high physical activity and meeting WHO recommendations were independently associated with lower all-cause mortality, while longer sitting time increased risk, consistent with the graded associations we observed [81].

In Greece, nationwide health examination data (EMENO, 2013–2016) revealed high burdens of hypertension, diabetes, dyslipidemia and obesity among adults, underscoring the preventive potential of physical activity at the population level [82]. Earlier Greek epidemiology linked walking/exercise with lower odds of obesity and cardiometabolic comorbidities, particularly among men, aligning with our sex-specific trends [83]. Moreover, a recent Greek cohort (ATTICA) showed that higher adherence to the Mediterranean diet was associated with lower 20-year incidence of hypertension, even after adjustment for lifestyle factors including physical activity; this supports the complementary role of diet and activity in cardiometabolic risk reduction [84].

In Italy, longitudinal cohort data (EPIC-Italy) indicate that individuals with lower socioeconomic position are more likely to be inactive and to decrease physical activity over time, compatible with the financial/education gradients we observed [85]. In the SUN cohort (Mediterranean population), low Mediterranean diet adherence combined with low

physical activity jointly increased premature mortality risk more than either alone (additive interaction), reinforcing our interpretation that diet–activity combinations contribute to broader health benefits [86].

From a policy/health-system perspective, Portugal has embedded physical activity assessment, brief counseling and digital self-monitoring into primary care information systems, with >119,000 patients assessed and thousands receiving brief PA interventions—illustrating scalable levers that could reduce healthcare burden via activity promotion [87]. Portugal's policy benchmarking (MOVING index) also highlights strengths in health-care-based PA counseling and remaining gaps in built-environment support, offering context for implementation beyond our setting [88].

Additional Mediterranean country profiles emphasize heterogeneity in adult activity levels and national HEPA infrastructures. For example, Cyprus country fact-sheets summarize prevalence, surveillance and "Sports for All" initiatives [89]. In Türkiye, repeated cross-sectional data (2014 vs. 2023) found persistently high inactivity and lower physical activity among women and older adults, mirroring our gradients and highlighting the need for tailored interventions [90]. At the European level, analyses across 28 Member States show that roughly one-third of adults are inactive, with women and older adults less active than younger men, patterns that correspond to our subgroup findings and support generalization beyond Greece [91].

At the policy level, there is an urgent need for the development and implementation of strategies aimed at promoting physical activity across all life stages. Initiatives could include urban planning that encourages active transportation, workplace wellness programs, school-based physical activity curricula, and the integration of exercise prescriptions into primary healthcare settings. Special attention should be given to reducing barriers to physical activity, such as socioeconomic disadvantage, physical disabilities, or environmental constraints. Considering the ongoing challenges posed by aging populations and the rising prevalence of non-communicable diseases, promoting physical activity represents not only a critical public health priority but also a cost-effective strategy for ensuring the sustainability of healthcare systems.

The strengths of this study include its large sample size, high participation rate, and the comprehensive evaluation of both physical and mental health outcomes, as well as healthcare utilization metrics. The use of a two-stage stratified random sampling method ensured the sample was representative, allowing the results to be generalized to the broader Thrace population.

However, several limitations should be acknowledged. First, the cross-sectional design precludes the ability to draw causal inferences. Although strong associations were observed, temporal relationships between physical activity and health outcomes cannot be established. Longitudinal studies are needed to confirm causality. Building on these findings, future research should pursue longitudinal cohort studies to better elucidate the causal relationships between physical activity and various health outcomes. Interventional studies are also needed to evaluate the efficacy of targeted physical activity programs in reducing disease incidence and healthcare usage across different demographic groups [71–75]. The level of physical activity was self-reported instead of measured with an objective instrument (such as a pedometer or accelerometer). However, IPAQ is a valid, widely used instrument to assess physical activity, so our findings can be compared to other observational studies. Moreover, based on evidence from other similar observational studies, hypertension was defined as SBP $\geq$ 140 mmHg, DBP $\geq$ 90 mmHg, or the use of antihypertensive medication. The diagnostic threshold for hypertension has changed recently (SBP $\geq$ 130 mmHg, DBP $\geq$ 80 mmHg), and since the nature of our data does not allow us to reconstruct the data and recalculate the outcomes, and assuming that this

concern applies only to a small proportion of the overall study sample, we consider this a limitation of our study. Finally, findings must be interpreted with caution as the sample was highly heterogeneous in terms of age.

5. Conclusions

In conclusion, this study provides strong evidence that even moderate-intensity physical activity was independently associated with improved physical health, as it was linked to lower prevalence of chronic diseases and better anthropometric profiles. It was also associated with mental health outcomes and decreased healthcare utilization among adults in Northern Greece. Policymakers, healthcare providers, and community leaders should prioritize the promotion of physical activity as a fundamental component of health promotion strategies. By fostering environments that support active living, we can move toward healthier, more resilient and well-being populations while simultaneously reducing the economic and social burdens associated with inactivity-related diseases.

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