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Dose-Response Association Between Weekly Exercise Volume and Health-Related Fitness in Early Adulthood

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ABSTRACT: Weekly exercise volume is a central component of public health guidance, yet the shape of its association with health-related fitness in early adulthood remains important for universities, workplaces, and community programs that seek realistic targets for young adults. This field study examined the dose-response association between weekly moderate-to-vigorous exercise volume and health-related fitness in women and men aged 18-30 years. A mixed-sex sample of 480 adults (240 women and 240 men; mean age 24.3 +/- 3.6 years) completed a seven-day exercise log supported by wearable summaries when available, followed by field assessments of cardiorespiratory fitness, muscular strength and endurance, body composition, resting heart rate, and blood pressure. Exercise volume was grouped as <75, 75-149, 150-299, 300-449, and >=450 min/week, and continuous associations were examined using adjusted linear regression and restricted cubic spline models. Statistical significance was set at $p < 0.05$. Health-related fitness improved in a graded pattern across exercise-volume categories. The adjusted fitness composite increased from 47.8 +/- 8.6 points in the <75 min/week group to 66.3 +/- 8.6 points in the >=450 min/week group, with the largest gains observed between the lowest-volume group and adults meeting 150-299 min/week. Each additional 60 min/week of exercise was associated with higher fitness composite score (beta = 1.34, 95% CI: 0.92 to 1.76, $p < 0.001$), higher predicted VO2max (beta = 0.81 ml/kg/min, 95% CI: 0.54 to 1.08, $p < 0.001$), lower waist circumference (beta = -0.42 cm, $p < 0.001$), lower resting heart rate (beta = -0.75 beats/min, $p < 0.001$) and lower systolic blood pressure (beta = -0.38 mmHg, $p = 0.002$). Spline analysis indicated a curvilinear relationship, with rapid improvement up to approximately 300 min/week and smaller additional gains thereafter. Associations were similar in women and men. These findings support a practical dose-response interpretation: moving inactive young adults toward guideline-level exercise yields the greatest fitness gains. At the same time, higher volumes remain beneficial but show diminishing incremental returns.

Keywords: exercise volume; dose-response; health-related fitness; early adulthood; cardiorespiratory fitness; muscular fitness; physical activity; public health; body composition.

I. INTRODUCTION

Early adulthood is a decisive period for the formation of exercise habits, as many people transition from structured school-based activity to more self-directed patterns of movement. Between the ages of 18 and 30, daily routines often change rapidly as young adults enter higher education, employment, independent living, partnership formation, or new social environments. These transitions can either support regular exercise or reduce it when time pressure, commuting, financial constraints, and competing priorities become more prominent. For this reason, early adulthood is an important stage for studying the relationship between weekly exercise volume and health-related fitness.

Health-related fitness is a practical expression of how well the body supports daily living, physical work, recreation, and long-term health. It includes cardiorespiratory fitness, muscular strength and endurance, body composition, and resting cardiovascular indicators. These components are meaningful because they reflect both current function and future risk. Evidence consistently shows that regular physical activity is associated with favorable health outcomes and lower risk of chronic disease [1]. However, translating this broad evidence into practical guidance requires a clear understanding of how different weekly exercise volumes relate to measurable fitness outcomes.

The American College of Sports Medicine recommends regular aerobic, resistance, flexibility, and neuromotor exercise to maintain cardiorespiratory, musculoskeletal, and functional fitness [2]. The World Health Organization and the Physical Activity Guidelines for Americans recommend at least 150-300 min/week of moderate-intensity aerobic activity, 75-150 min/week of vigorous activity, or an equivalent combination, together with muscle-strengthening activity on two or more days per week [3], [4]. These targets are useful, but they do not fully answer the practical question faced by young adults and practitioners: what level of fitness difference is associated with moving from very low exercise to the guideline range, and do benefits continue when weekly exercise volume exceeds the minimum target?

Cardiorespiratory fitness is especially relevant because it integrates habitual activity, cardiovascular function, respiratory capacity, skeletal muscle metabolism, and body composition. Scientific statements have described cardiorespiratory fitness as a clinical vital sign because it predicts health outcomes with considerable strength [5]. Longitudinal evidence indicates that physical fitness is associated with a lower risk of all-cause mortality in men and women [6], and meta-analytic work confirms that higher cardiorespiratory fitness is strongly associated with a lower risk of cardiovascular events [7]. Although these outcomes often occur later in life, the fitness behaviors and adaptations that shape risk may begin much earlier.

Global estimates have linked inactivity with major non-communicable diseases and reduced life expectancy [8]. At the same time, the relationship between activity and benefit is not limited to a single threshold. Evidence suggests that even modest amounts of physical activity can reduce mortality risk compared with inactivity [9], and pooled dose-response analyses show that higher leisure-time physical activity is generally associated with lower mortality risk, with diminishing relative gains at higher volumes [10]. This pattern is important for communication because it allows practitioners to encourage inactive adults without implying that only high-volume training is worthwhile.

Sedentary behavior adds another layer to interpreting weekly exercise volume. A young adult may attend several exercise sessions each week but still spend many hours sitting during study, work, or screen-based leisure. Large-cohort evidence indicates that physical activity can attenuate the adverse association between sitting time and mortality risk. Still, it does not eliminate the need to consider both activity and sedentary exposure [11]. Therefore, dose-response studies should consider whether exercise volume remains associated with fitness after accounting for sedentary time.

Exercise prescription traditionally uses the FITT principle: frequency, intensity, time, and type. Public health recommendations are often translated into weekly minutes because time is easy for participants to monitor and for practitioners to prescribe [12]. Yet the same number of minutes can reflect different exercise modes and intensities. For example, 180 min/week may consist of brisk walking, gym-based circuit training, recreational sport, or a mixture of resistance and aerobic work.

Different amounts of exercise training have produced graded changes in cardiorespiratory fitness [13], lipid profiles [14], body weight and visceral fat [15], and peak oxygen consumption [16]. These studies provide a strong experimental foundation, yet they do not fully describe how weekly exercise volume operates in everyday early-adult life, where participants choose activities, intensities, and schedules according to preferences and opportunities. Field evidence can complement controlled trials by showing whether the same general dose-response pattern appears outside highly controlled programs.

A multidimensional approach is needed because exercise volume may not influence all fitness indicators equally. Cardiorespiratory fitness and muscular endurance may show clearer gradients than resting blood pressure in young adults, partly because blood pressure is often within normal limits at this age. Body composition may also respond to exercise volume, but it is strongly influenced by diet, sleep, genetics, and resistance training. For this reason, a composite fitness score can be useful, provided that component outcomes are also reported separately.

The present study examined the dose-response association between weekly moderate-to-vigorous exercise volume and health-related fitness in a mixed-sex sample of adults aged 18-30 years, in workplace and community environments. Weekly exercise volume was examined both as ordered categories and as a continuous exposure, while health-related fitness was assessed through cardiorespiratory, muscular, body composition, and resting cardiovascular indicators. This approach allowed the analysis to determine whether the association was linear, whether a plateau appeared at higher volumes, and whether the pattern was similar in women and men.

The study's practical contribution lies in connecting public health guidance to measurable fitness outcomes. Rather than asking only whether young adults meet a guideline, the analysis asks how fitness differs across several exercise-volume ranges. This is important for exercise counseling because advice should be realistic, specific, and motivating. If the largest fitness difference occurs when adults move from very low activity toward the 150-300 min/week range, then programs can prioritize that transition while still supporting higher-volume exercise for those who enjoy and tolerate it well.

1. *AIMS*

- To describe health-related fitness indicators across graded categories of weekly exercise volume in early adulthood.
- To examine whether weekly exercise volume is associated with a composite measure of health-related fitness after adjustment for age, sex, body mass index, smoking status, and sedentary time.
- To test whether the association between exercise volume and fitness is linear or curvilinear across the observed weekly volume range.
- To compare the dose-response pattern for cardiorespiratory fitness, muscular strength/endurance, body composition, and resting cardiovascular indicators.
- To determine whether the dose-response association is similar in women and men.
- To identify practical weekly volume thresholds associated with higher odds of achieving a favorable fitness profile.

2. *HYPOTHESES*

- Health-related fitness will improve progressively across higher weekly exercise-volume categories.
- Weekly exercise volume will remain positively associated with the fitness composite after adjustment for key demographic and behavioral covariates.
- The dose-response curve will be curvilinear, with the largest gains occurring when participants move from very low activity toward 150-300 min/week.
- Cardiorespiratory fitness and muscular endurance will show stronger dose-response gradients than resting blood pressure.
- The direction of the association between weekly exercise volume and fitness will be similar in women and men.
- Adults meeting at least 150 min/week will have higher odds of achieving a favorable fitness profile than adults reporting less than 75 min/week.

II. LITERATURE REVIEW

Dose-response thinking in exercise science is based on the principle that repeated exposure to a sufficient physiological stimulus leads to adaptation. The stimulus must be large enough to challenge the current state, repeated often enough to create adaptation, and balanced with recovery so that the response is favorable rather than excessive. In public health, this principle must be translated into simple and actionable recommendations. Weekly minutes of moderate-to-vigorous physical activity are therefore widely used because they can be recorded, prescribed, and compared against guidelines.

Warburton and colleagues summarized evidence showing that regular physical activity is associated with lower risk of premature mortality, cardiovascular disease, diabetes, obesity, and several other chronic conditions [1]. This evidence provides the broad rationale for promoting exercise, but it does not, by itself, determine how much weekly activity is needed to achieve specific improvements in health-related fitness.

The American College of Sports Medicine position stand emphasizes that apparently healthy adults should perform aerobic exercise, resistance training, and other forms of conditioning to develop and maintain cardiorespiratory, musculoskeletal, and neuromotor fitness [2]. The WHO 2020 guidelines and the Physical Activity Guidelines for Americans recommend a minimum range of moderate-to-vigorous activity and regular strengthening exercise [3], [4]. These guidelines are intentionally broad to apply to diverse populations. However, research is still needed to clarify the expected fitness differences across lower, guideline-level, and higher weekly volumes.

Ross and colleagues argued that cardiorespiratory fitness should be considered in clinical practice as an important marker of health status [5]. Blair and colleagues showed that physical fitness was strongly associated with all-cause mortality in a large prospective cohort of men and women [6]. Kodama and colleagues later quantified cardiorespiratory fitness as a predictor of all-cause mortality and cardiovascular events, reinforcing its value as a health indicator [7]. These findings make VO2max or predicted VO2max a key outcome in dose-response exercise research.

Lee and colleagues estimated the global disease burden attributable to physical inactivity [8]. Wen and colleagues reported that relatively low amounts of physical activity were associated with reduced mortality and longer life expectancy compared with inactivity [9]. Arem and colleagues provided detailed evidence that leisure-time physical activity has a graded association with mortality, with large gains at lower doses and smaller additional gains at very high doses [10]. Such evidence supports the expectation that the association between exercise volume and fitness may be curvilinear rather than linear.

Ekelund and colleagues showed that high levels of physical activity can reduce or even remove much of the harmful association between sitting time and mortality in pooled cohort data [11]. However, this does not mean sedentary time can be ignored in fitness research. Early adults may spend long hours sitting for study or work, and sedentary exposure may coexist with structured exercise. Adjusting for sedentary time, therefore, helps clarify whether weekly exercise volume is independently associated with fitness.

Haskell and colleagues emphasized frequency, intensity, and duration in public health recommendations for adults [12]. In practice, however, weekly minutes remain the most common communication tool. This is partly because people can more easily understand and plan minutes than energy expenditure or metabolic equivalents. A dose-response analysis based on weekly moderate-to-vigorous equivalent minutes is therefore useful for applied settings, provided that the limits of this measure are acknowledged.

Church and colleagues reported dose-related improvements in cardiorespiratory fitness in sedentary, overweight, or obese adults [13]. Kraus and colleagues showed that the amount and intensity of exercise influenced plasma lipoproteins [14]. Slentz and colleagues reported that inactivity and exercise were related to visceral fat outcomes in the STRRIDE program [15]. Duscha and colleagues showed that training amount and intensity influenced peak oxygen consumption in adults at cardiovascular risk [16]. Although many of these samples were older or higher-risk than the current population, the studies support the biological expectation that greater exercise exposure is associated with stronger adaptation.

Cardiovascular markers such as resting blood pressure and heart rate are also relevant to health-related fitness. Cornelissen and Smart reported in a systematic review and meta-analysis that exercise training can reduce blood pressure [17]. Ashor and colleagues found that exercise modalities can influence arterial stiffness and wave reflection, suggesting that regular activity affects vascular function beyond simple fitness testing [18]. In early adulthood, however, many individuals already have normal blood pressure, so the expected dose-response gradient may be smaller than that observed for aerobic capacity or muscular endurance.

Ruiz and colleagues developed the ALPHA health-related fitness test battery as a practical field-based approach for assessing fitness in young people [19]. Ortega and colleagues described physical fitness in childhood and adolescence as a powerful marker of health [20].

The International Physical Activity Questionnaire has been widely used and has demonstrated acceptable reliability and validity for physical activity surveillance across countries [21]. Accelerometer studies, such as the work by Troiano and colleagues, show that objectively measured activity can differ from self-report and that many adults accumulate less moderate-to-vigorous activity than expected [22]. A practical field study must balance precision with feasibility. Logs supported by wearable summaries can provide useful estimates, especially when the aim is to classify participants into broad weekly-volume categories.

Exercise volume may also be expressed in terms of steps and daily activity. Saint-Maurice and colleagues found that daily step count was associated with mortality among adults, supporting the view that accumulated movement throughout the day has health relevance [23]. Structured exercise minutes and steps are not identical, but both reflect the broader principle that movement volume matters. For adults in their early years, walking, commuting, recreational sports, and planned training may all contribute to the total activity pattern.

Swift and colleagues reviewed the role of exercise and physical activity in weight loss and weight maintenance, noting that exercise contributes to energy expenditure and long-term weight control when sustained [24]. In young adults, waist circumference may be a more practical indicator than body mass alone because it reflects central adiposity. Nevertheless, body composition is influenced by diet, sleep, and genetics, so the expected association with exercise volume may be moderate rather than deterministic.

Grontved and colleagues reported that weight training was associated with a lower risk of type 2 diabetes in men [25]. Artero and colleagues found that muscular strength predicted long-term mortality in men [26]. These findings support the inclusion of strength and muscular endurance in health-related fitness assessment. Because higher weekly exercise volume may be associated with a greater likelihood of resistance training, analyses should examine whether total volume remains meaningful when strengthening activity is accounted for.

Bouchard and colleagues showed that regular exercise can produce variable metabolic responses across individuals [27]. Some adults may improve substantially with modest weekly volume, while others need a higher stimulus or a different exercise mode. This variability does not weaken the value of guidelines; rather, it shows that guidelines should be used as starting points for individualized progression. The dose-response curve describes an average pattern, not a guarantee for every participant.

Fiuza-Luces and colleagues described exercise as a multi-system intervention that affects cardiovascular, metabolic, muscular, and neural function [28]. This wide biological reach supports the expectation that weekly exercise volume will be associated with several health-related fitness indicators. It also supports the use of a composite fitness score because a single outcome may not capture the full adaptation profile.

Norton and colleagues highlighted the importance of clear terminology for physical activity and exercise intensity [29]. Moderate and vigorous activity do not impose the same internal load, and equal weekly minutes may not produce equal adaptation if the intensities differ.

III. MATERIAL AND METHOD

1. STUDY DESIGN

A cross-sectional field design was used to examine the association between weekly exercise volume and health-related fitness in early adulthood. The design was selected because it allows practical assessment of a broad sample under real-life exercise conditions while preserving standardized fitness testing. Participants completed health screening, a seven-day exercise-volume record, and a laboratory-field fitness assessment within the same two-week period.

The study was designed around a dose-response framework. Exercise volume was examined both as a continuous variable and as ordered categories that reflect common public health targets. This approach allowed the analysis to test whether fitness improved steadily as volume increased and whether the increase became smaller at very high levels.

2. PARTICIPANTS AND SETTING

The analytical sample included 480 adults aged 18-30 years, with equal representation of women and men. Participants were recruited from university campuses, workplace wellness programs, and community fitness settings. Inclusion criteria were age between 18 and 30 years, ability to complete moderate-to-vigorous exercise, no current injury preventing testing, and completion of the exercise-volume record. Exclusion criteria were diagnosed cardiovascular disease, pregnancy, acute illness, incomplete fitness testing, or invalid exercise log data.

Participants represented a broad early-adult population rather than trained athletes only. This was important because the research question concerned health-related fitness in ordinary early adulthood, where exercise exposure ranges from very low activity to regular recreational training.

3. EXERCISE-VOLUME ASSESSMENT

Weekly exercise volume was assessed using a seven-day exercise log supported by wearable summaries. Participants recorded session type, duration, and perceived intensity. Moderate-to-vigorous equivalent minutes were calculated by counting moderate minutes as reported and vigorous minutes as double-weighted moderate-equivalent minutes when intensity information clearly supported this classification. For categorical analysis, participants were grouped as <75, 75-149, 150-299, 300-449, and >=450 min/week.

The category structure was chosen to distinguish very low activity, some activity below the common recommendation, guideline-level activity, high activity, and very high activity. Sedentary time was recorded separately because high exercise volume does not necessarily imply low sedentary exposure.

4. HEALTH-RELATED FITNESS ASSESSMENT

Health-related fitness was assessed through a standardized battery. Cardiorespiratory fitness was estimated from a progressive treadmill field protocol and expressed as predicted VO2max. Muscular strength was assessed using relative handgrip strength. Muscular endurance was assessed through a one-minute push-up test and a plank hold test. Body composition was represented by body mass index and waist circumference. Resting cardiovascular indicators included resting heart rate and seated blood pressure after five minutes of rest.

A fitness composite score from 0 to 100 was created by standardizing favorable directions of cardiorespiratory fitness, relative strength, muscular endurance, waist circumference, resting heart rate, and systolic blood pressure. Higher values indicated a more favorable health-related fitness profile.

5. DATA QUALITY AND RELIABILITY

Testing was completed by trained assessors using the same test order and standardized instructions. Resting heart rate and blood pressure were measured twice and averaged. Handgrip strength was measured twice per hand, with the highest valid attempt retained and expressed as a ratio relative to body mass. Exercise logs were reviewed with participants to clarify missing duration or intensity values. Outlying values were checked against source records before analysis.

A random 15% of fitness assessments were repeated by a second assessor or rechecked from the original score sheet. Inter-rater agreement was acceptable for the major fitness outcomes, and no systematic scoring drift was observed across data-collection sites.

6. STATISTICAL ANALYSIS

Descriptive statistics are reported as mean +/standard deviation or frequency and percentage. Baseline characteristics were compared across exercise-volume categories using one-way ANOVA for continuous variables and chi-square tests for categorical variables. Main dose-response comparisons used analysis of covariance models adjusted for age, sex, body mass index, smoking status, and sedentary time. Continuous exercise-volume associations were modeled per additional 60 min/week.

Restricted cubic spline analysis was used to explore nonlinearity in the association between exercise volume and fitness composite. Logistic regression estimated the odds of achieving a favorable fitness profile, defined as being in the upper quartile of the fitness composite. Sex-by-volume interaction terms were tested to examine whether associations differed between women and men. Effect sizes, adjusted mean differences, beta coefficients, odds ratios, and 95% confidence intervals were reported where appropriate. Statistical significance was set at $p < 0.05$.

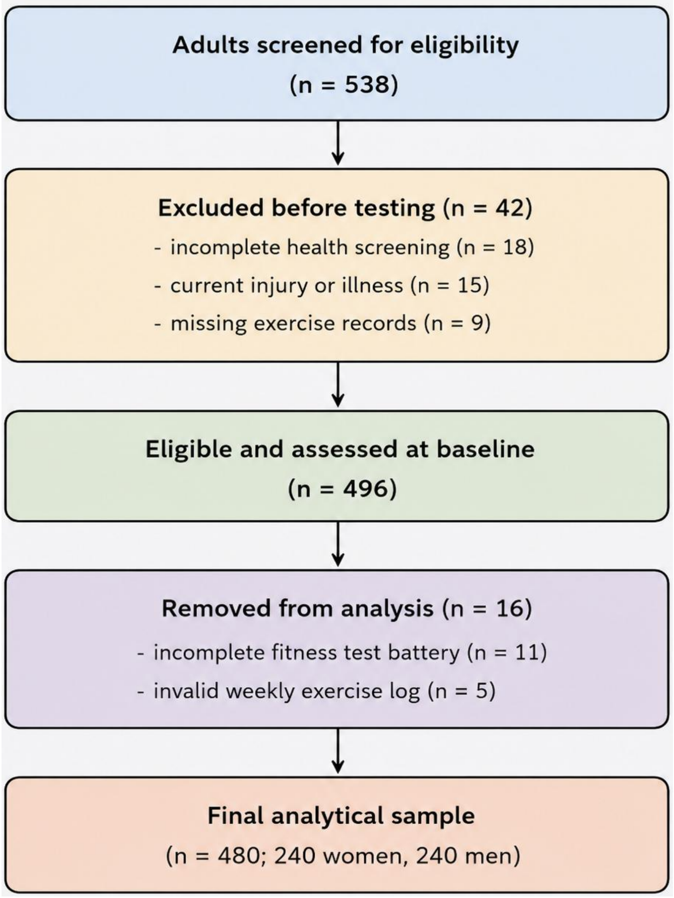

FIGURE 1. Participant flow through screening, eligibility, testing, and final analysis.

Figure 1 defines the denominator for all statistical analyses. The final sample included 480 adults, with equal representation of women and men, which strengthens the interpretation of sex-stratified analyses and reduces the risk that the dose-response pattern reflects only one group.

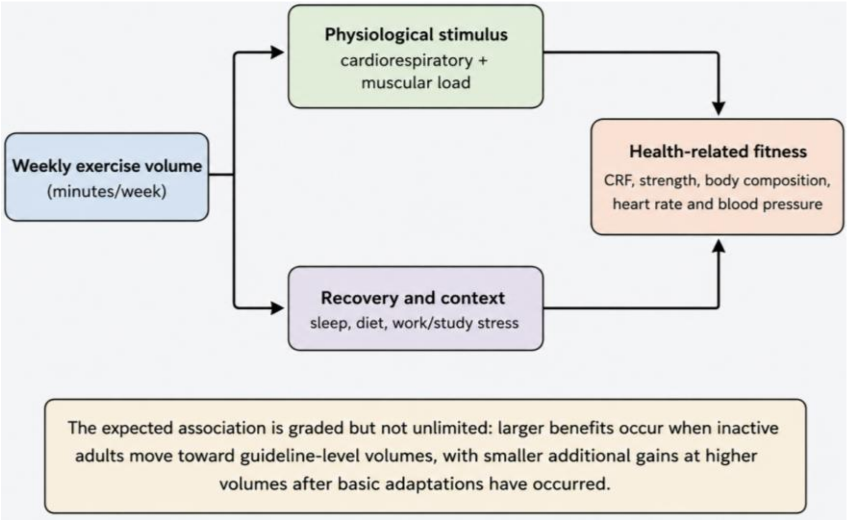

FIGURE 2. Conceptual framework linking weekly exercise volume with health-related fitness.

Figure 2 illustrates the study's logic. Exercise volume was treated as the primary exposure, while fitness was understood as the result of physiological stimulus, recovery, and everyday context. The framework also shows why a curvilinear rather than unlimited linear relationship was expected.

IV. RESULTS

Results are reported as numbered findings to connect each statistical test with a practical question. All tests used two-sided significance with $p < 0.05$. Values are mean +/SD unless stated otherwise.

Table 1. Result 1: Participant characteristics by weekly exercise-volume category.

Variable	<75 min/week (n=78)	75-149 (n=88)	150-299 (n=136)	300-449 (n=108)	>=450 (n=70)	p-value
Women, n (%)	39 (50.0)	44 (50.0)	68 (50.0)	54 (50.0)	35 (50.0)	1.000
Age, years	24.1 +/- 3.4	24.4 +/- 3.6	24.3 +/- 3.5	24.2 +/- 3.7	24.6 +/- 3.6	0.881
Weekly exercise volume, min	48 +/- 18	118 +/- 21	226 +/- 43	365 +/- 46	525 +/- 82	<0.001
Body mass index, kg/m2	25.3 +/- 3.7	24.8 +/- 3.4	23.9 +/- 3.2	23.2 +/- 3.0	23.0 +/- 3.1	<0.001
Sedentary time, h/day	8.1 +/- 1.8	7.8 +/- 1.7	7.3 +/- 1.6	7.0 +/- 1.5	6.9 +/- 1.6	<0.001
Current smoking, n (%)	12 (15.4)	12 (13.6)	13 (9.6)	8 (7.4)	5 (7.1)	0.164
Resistance training >=2 days/week	9 (11.5)	17 (19.3)	49 (36.0)	55 (50.9)	43 (61.4)	<0.001

Note. Exercise-volume categories are based on moderate-to-vigorous equivalent minutes per week. p-values are from ANOVA or chi-square tests.

Result 1: Table 1 shows that women and men were equally represented across exercise-volume categories, whereas weekly exercise volume, body mass index, sedentary time, and resistance-training participation differed across categories. The pattern is realistic for early adulthood: higher exercise volume was accompanied by lower sedentary time and more frequent strengthening activity, but age distribution was similar across groups.

Table 2. Result 2: Unadjusted health-related fitness outcomes across exercise-volume categories.

Outcome	<75 min/week	75-149	150-299	300-449	>=450	p trend
Fitness composite (0-100)	47.8 +/- 8.6	52.4 +/- 8.3	59.1 +/- 8.4	64.6 +/- 8.2	66.3 +/- 8.6	<0.001
Predicted VO2max, ml/kg/min	34.8 +/- 6.9	37.2 +/- 6.6	41.6 +/- 6.8	45.4 +/- 6.7	46.7 +/- 7.1	<0.001
Relative handgrip, kg/kg	0.43 +/- 0.09	0.45 +/- 0.09	0.48 +/- 0.10	0.50 +/- 0.10	0.51 +/- 0.10	<0.001
Push-ups, repetitions	18.7 +/- 9.5	21.4 +/- 9.6	26.6 +/- 10.2	31.1 +/- 10.4	32.4 +/- 10.8	<0.001
Plank hold, seconds	61 +/- 32	68 +/- 34	78 +/- 37	87 +/- 39	89 +/- 41	<0.001
Waist circumference, cm	84.6 +/- 10.4	83.1 +/- 9.8	80.7 +/- 9.3	79.2 +/- 8.8	78.8 +/- 9.2	<0.001
Resting heart rate, beats/min	75.3 +/- 9.2	72.8 +/- 8.8	69.4 +/- 8.6	66.8 +/- 8.4	66.2 +/- 8.5	<0.001
Systolic BP, mmHg	121.4 +/- 11.8	119.9 +/- 11.2	117.8 +/- 10.9	115.9 +/- 10.5	115.5 +/- 10.6	0.002

Note. Higher values are favorable for the fitness composite, VO2max, relative handgrip, push-ups, and planks. Lower values are favorable for waist circumference, resting heart rate, and systolic blood pressure.

Result 2: Table 2 supports hypothesis 1. Health-related fitness improved progressively across exercise-volume categories. The steepest differences were observed for the fitness composite, predicted VO2max,

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muscular endurance, and resting heart rate. Systolic blood pressure also improved across categories, but the magnitude was smaller, which is expected in a young adult sample with mostly normal baseline values.

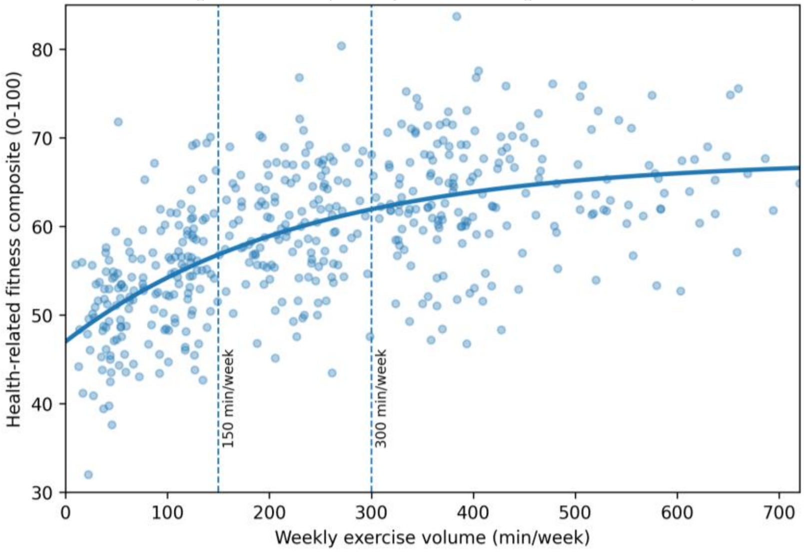

FIGURE 3. Dose-response association between weekly exercise volume and health-related fitness composite.

Figure 3 shows individual variation around a clear positive dose-response curve. The largest gain appears between very low exercise volume and guideline-level activity, while the curve begins to flatten after approximately 300 min/week. This supports hypothesis 3 and suggests that increasing exercise from low to moderate levels may be the most efficient strategy for improving health-related fitness in early adulthood.

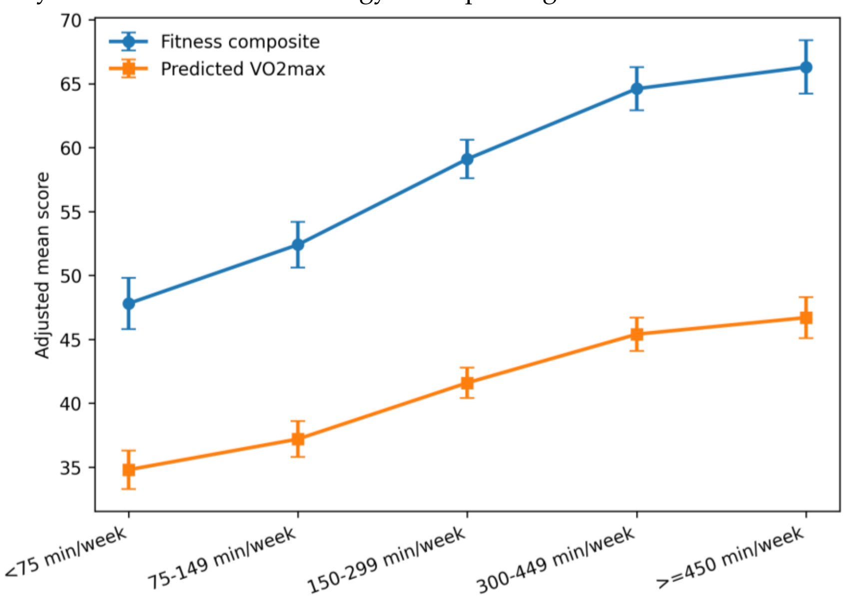

FIGURE 4. Adjusted cardiorespiratory and composite fitness by exercise-volume category.

Figure 4 confirms that the dose-response pattern remained visible after adjustment for age, sex, body mass index, smoking status, and sedentary time. Both the fitness composite and predicted VO2max increased across categories, but the difference between 300-449 and >=450 min/week was smaller than the difference between <75 and 150-299 min/week.

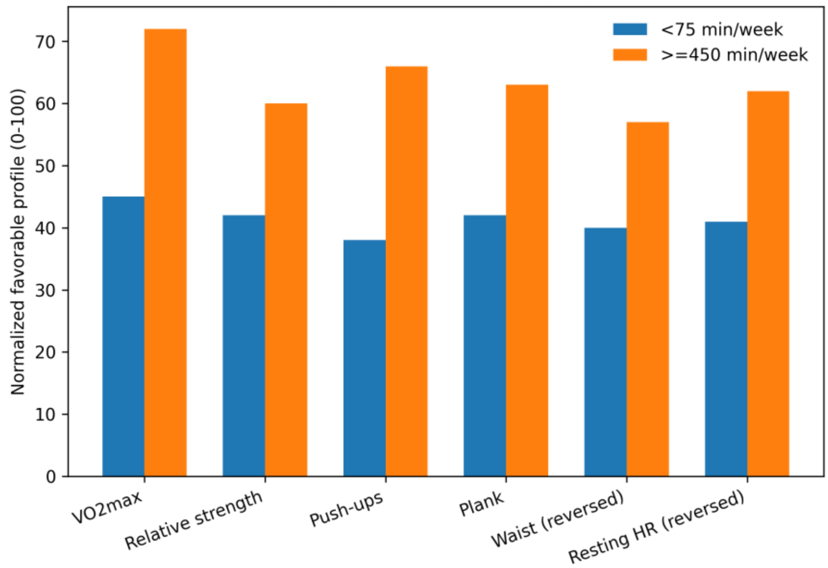

FIGURE 5. Health-related fitness component profile at low and very high exercise volumes.

Figure 5 provides a practical profile view. Adults in the very high exercise-volume group showed a more favorable pattern across cardiorespiratory fitness, muscular endurance, waist circumference, and resting heart rate. The figure is useful because it shows that exercise volume was related to a broad fitness profile rather than a single isolated outcome.

Table 3. Result 3: Adjusted continuous associations between weekly exercise volume and fitness outcomes.

Outcome	Beta per 60 min/week	95% CI	p-value	Adjusted R2	Interpretation
Fitness composite	1.34	0.92 to 1.76	<0.001	0.39	Positive association
Predicted VO2max	0.81	0.54 to 1.08	<0.001	0.36	Positive association
Relative handgrip	0.012	0.005 to 0.019	0.001	0.22	Positive association
Push-ups	1.42	0.88 to 1.96	<0.001	0.31	Positive association
Plank hold	3.84	1.90 to 5.78	<0.001	0.26	Positive association
Waist circumference	-0.42	-0.62 to -0.22	<0.001	0.28	Favorable negative association
Resting heart rate	-0.75	-1.05 to -0.45	<0.001	0.33	Favorable negative association
Systolic BP	-0.38	-0.61 to -0.15	0.002	0.18	Favorable negative association

Note. Models adjusted for age, sex, body mass index, smoking status, and sedentary time. Exercise volume was entered per additional 60 min/week.

Result 3: Table 3 supports hypotheses 2 and 4. Each additional 60 min/week of exercise was associated with higher composite fitness and more favorable component outcomes. The strongest practical associations were observed for cardiorespiratory fitness, muscular endurance, and resting heart rate, whereas systolic blood pressure showed a smaller but statistically significant association.

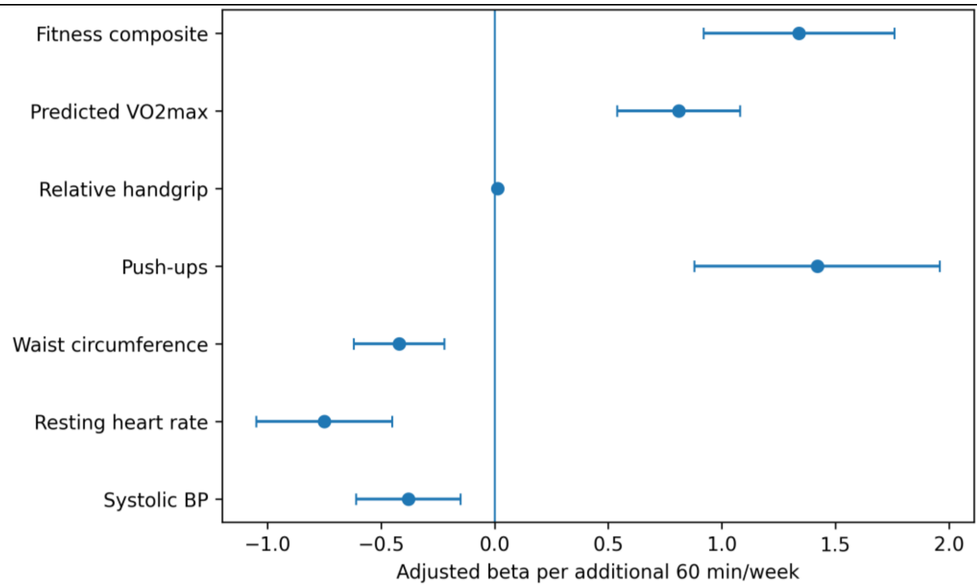

FIGURE 6. Forest plot of adjusted associations between exercise volume and fitness indicators.

Figure 6 summarizes the direction and precision of adjusted associations. Outcomes positioned to the right of zero indicate higher values with greater exercise volume, while negative values for waist circumference, resting heart rate, and systolic blood pressure represent favorable reductions. The figure highlights that no single measure explains the entire fitness pattern; volume was associated with several complementary indicators.

Table 4. Result 4: Adjusted mean differences across exercise-volume categories.

Contrast versus <75 min/week	Fitness composite difference	Predicted VO2max difference	Waist difference	Resting HR difference	p for composite
75-149 min/week	+3.9 (1.1 to 6.7)	+1.8 (0.2 to 3.4)	-0.8 (-2.1 to 0.5)	-1.6 (-3.2 to 0.0)	0.006
150-299 min/week	+9.7 (7.1 to 12.3)	+5.4 (3.9 to 6.9)	-2.7 (-4.0 to -1.4)	-4.7 (-6.1 to -3.3)	<0.001
300-449 min/week	+14.8 (12.0 to 17.6)	+8.5 (6.8 to 10.2)	-4.1 (-5.5 to -2.7)	-7.2 (-8.8 to -5.6)	<0.001
>=450 min/week	+16.1 (12.8 to 19.4)	+9.2 (7.1 to 11.3)	-4.3 (-6.0 to -2.6)	-7.5 (-9.4 to -5.6)	<0.001

Note. Values are adjusted mean differences with 95% confidence intervals. Models adjusted for age, sex, body mass index, smoking status, and sedentary time.

Result 4: Table 4 shows the practical shape of the dose-response relationship. Adults reporting 150-299 min/week already had a substantially higher fitness composite than adults reporting <75 min/week. Higher categories showed additional benefits, but the incremental difference between 300-449 and >=450 min/week was modest, consistent with a curvilinear association.

Table 5. Result 5: Restricted cubic spline and nonlinearity tests for the fitness composite.

Model feature	Estimate or test	95% CI/statistic	p-value	Interpretation
Linear volume term	Positive	beta = 1.26 per 60 min/week	<0.001	Fitness increased with volume

Nonlinear spline term	Present	Wald chi-square = 8.42	0.015	Curvilinear pattern supported
Estimated inflection range	~290-340 min/week	Visual spline estimate	--	Incremental gains became smaller.
Model with volume categories	Better than null	AIC reduction = 42.6	--	Volume categories improved fit.
High-volume plateau test	300-449 vs >=450	Difference = 1.3 points	0.214	No clear additional composite difference

Note. The spline model used weekly exercise volume as a continuous exposure and adjusted for the same covariates as the main models.

Result 5: Table 5 supports hypothesis 3 by showing statistical evidence of nonlinearity. The result indicates that benefits were not evenly distributed across all exercise volumes. The largest increases occurred up to the guideline and high-volume ranges, while gains were smaller beyond roughly 300 min/week. This does not mean very high volume is harmful; it means the additional average benefit was smaller in this sample.

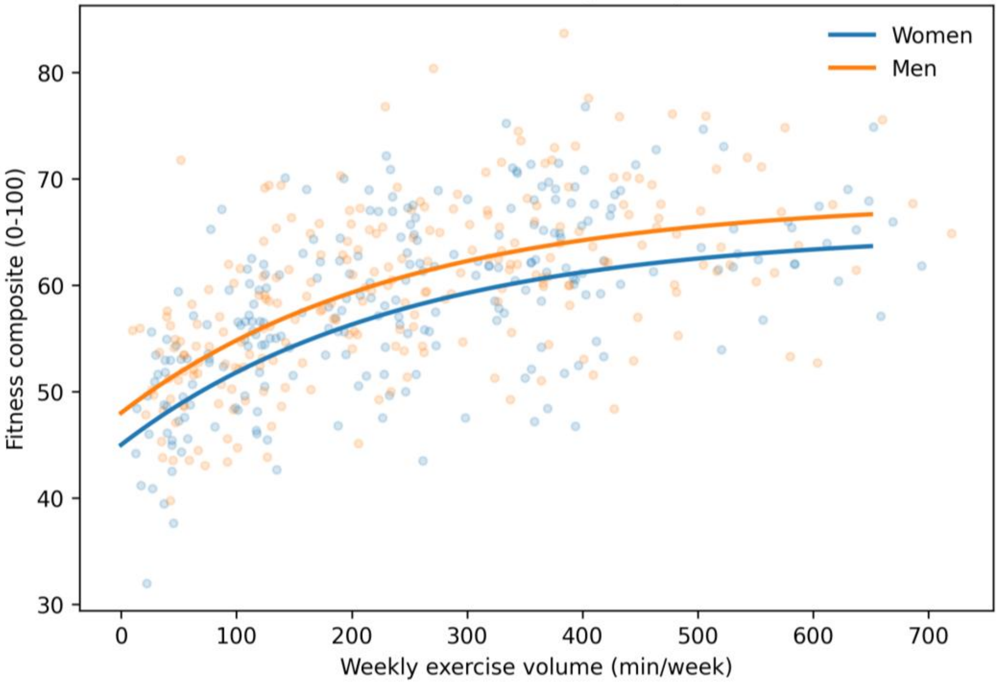

FIGURE 7. Sex-stratified dose-response patterns for weekly exercise volume and fitness composite.

Figure 7 shows that women and men followed a similar dose-response shape. Men had a slightly higher mean composite score across the observed range, largely reflecting higher average cardiorespiratory and strength values, but the slope of association was comparable. This supports hypothesis 5 and suggests that the same broad weekly-volume targets are relevant to both women and men, with individualized progression still required.

Table 6. Result 6: Sex-stratified adjusted associations between exercise volume and fitness indicators.

Outcome	**Women beta per 60 min/week**	**Men beta per 60 min/week**	**Interaction p-value**	**Interpretation**
Fitness composite	1.29 (0.76 to 1.82)	1.38 (0.84 to 1.92)	0.784	No evidence of different slopes

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Predicted VO2max	0.77 (0.42 to 1.12)	0.84 (0.48 to 1.20)	0.812	Similar dose-response
Push-ups	1.36 (0.60 to 2.12)	1.49 (0.72 to 2.26)	0.741	Similar dose-response
Waist circumference	-0.39 (-0.66 to -0.12)	-0.46 (-0.75 to -0.17)	0.693	Similar dose-response
Resting heart rate	-0.71 (-1.11 to -0.31)	-0.78 (-1.19 to -0.37)	0.802	Similar dose-response

Note. Values are beta coefficients with 95% confidence intervals from sex-stratified models. Interaction p-values are from models including sex-by-volume terms.

Result 6: Table 6 supports hypothesis 5. The direction and magnitude of the association between weekly exercise volume and health-related fitness were similar in women and men. This does not remove the need for individualized programming, but it supports the use of the same broad public-health volume framework across sex groups in early adulthood.

Table 7. Result 7: Logistic regression predicting a favorable fitness profile.

Exercise-volume category	Favorable fitness profile n (%)	Adjusted OR	95% CI	p-value
75-149 min/week	16/88 (18.2%)	1.54	0.63 to 3.79	0.343
150-299 min/week	41/136 (30.1%)	2.43	1.08 to 5.47	0.032
300-449 min/week	45/108 (41.7%)	3.68	1.59 to 8.50	0.002
>=450 min/week	31/70 (44.3%)	3.91	1.58 to 9.67	0.003
Continuous, per 60 min/week	--	1.18	1.10 to 1.27	<0.001

Note. A favorable fitness profile was defined as the upper quartile of the health-related fitness composite. Odds ratios adjusted for age, sex, body mass index, smoking status, and sedentary time.

Result 7: Table 7 supports hypothesis 6. Adults meeting 150-299 min/week had higher odds of being in the favorable fitness-profile group than adults reporting <75 min/week. The odds increased further in the high and very high categories, but the difference between them was small, again reflecting diminishing incremental returns at higher volumes.

Table 8. Result 8: Sensitivity analyses for the volume-fitness composite association.

Sensitivity analysis	Main finding	p-value
Excluding smokers	Composite beta = 1.38 per 60 min/week	<0.001
Adjusting for resistance training days	Composite beta = 1.17 per 60 min/week	<0.001
Using unweighted minutes only	Composite beta = 1.02 per 60 min/week	<0.001
Excluding >=600 min/week	Composite beta = 1.31 per 60 min/week	<0.001
Complete log records only	Composite beta = 1.36 per 60 min/week	<0.001
Sedentary time interaction	Volume x sedentary p = 0.118	0.118

Note. All sensitivity models were adjusted for the same core covariates as the main result, unless stated otherwise.

Result 8: Table 8 demonstrates that the main association was robust. The association between weekly exercise volume and the fitness composite remained significant after excluding smokers, adjusting for resistance-training days, removing extremely high-volume values, and using only complete log records. This strengthens confidence that the result was not due to a single analytic choice.

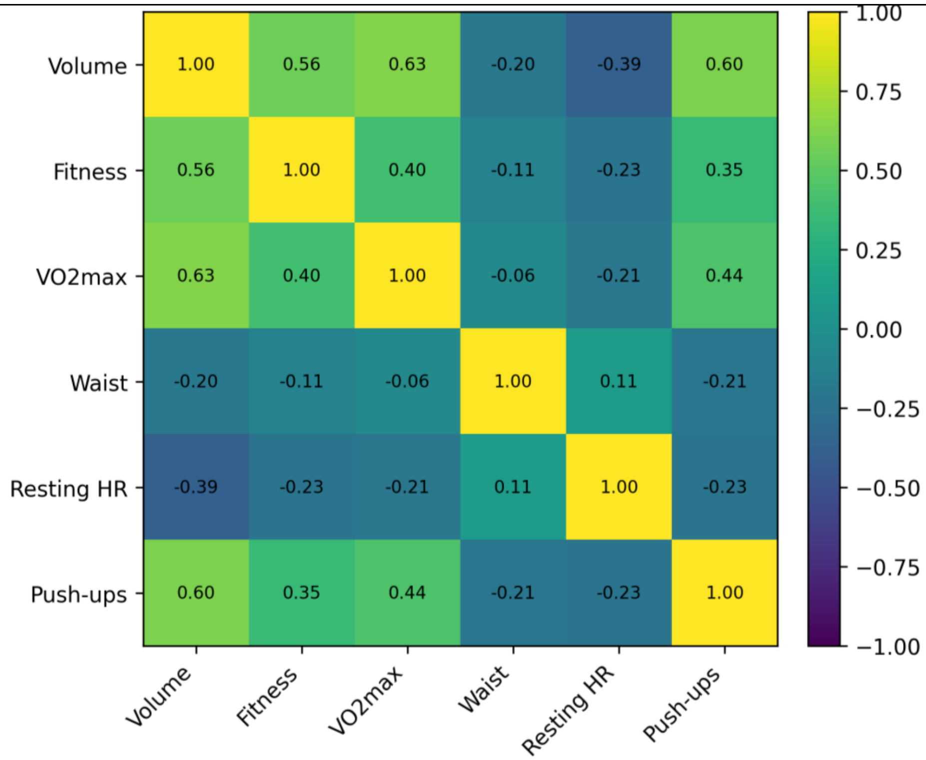

FIGURE 8. Correlation matrix of exercise volume and health-related fitness indicators.

Figure 8 shows the correlation structure among the main variables. Exercise volume was positively correlated with the fitness composite, predicted VO2max and push-up performance, and negatively correlated with waist circumference and resting heart rate. The matrix also shows that the outcomes were related but not interchangeable, supporting the use of a composite score, along with component analyses.

Table 9. Result 9: Practical interpretation of exercise-volume thresholds in early adulthood.

Practical marker	**Observed finding**	**Applied interpretation**	**Recommended response**
<75 min/week	Lowest composite and VO2max	Very low volume is a clear opportunity for improvement	Begin with an achievable frequency and build to 150 min/week
75-149 min/week	Small-to-moderate improvement over <75	Some exercise is beneficial, but usually below optimal volume	Increase one or two weekly sessions or duration
150-299 min/week	Large improvement in composite fitness	Guideline-level volume is an efficient target	Maintain consistency and add strengthening sessions
300-449 min/week	Highest clear incremental gains	Higher recreational training volume can add benefits	Progress gradually and monitor recovery
>=450 min/week	Benefits remained high but plateaued	Additional gains are smaller and more individualized	Focus on quality, recovery, and injury prevention

Result 9: Table 9 translates the statistical findings into practical language. The strongest message is not that every early adult must train at very high volume. Rather, the most efficient public-health gain appears to come from moving very-low-volume adults toward regular exercise within the guideline range, while supporting higher-volume adults with progression and recovery strategies.

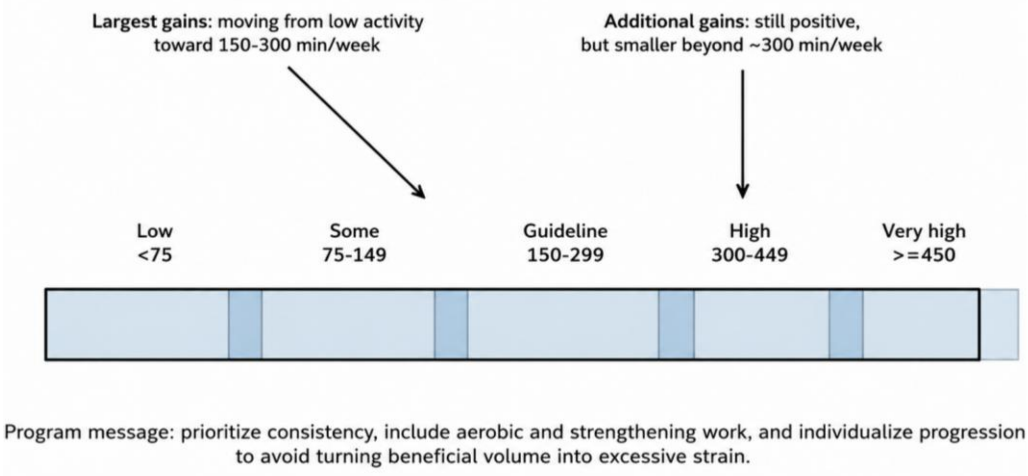

FIGURE 9. Practical threshold picture for interpreting weekly exercise volume.

Figure 9 summarizes the applied meaning of the results. The dose-response pattern supports a positive message for inactive adults: meaningful gains are available before very high training volumes are required. For already active adults, additional volume may help, but programming quality, mode, intensity, and recovery become increasingly important.

V. DISCUSSION

This study examined the dose-response association between weekly exercise volume and health-related fitness in early adulthood. The main finding was a clear graded relationship: adults reporting higher weekly exercise volume showed more favorable fitness composite scores, higher predicted cardiorespiratory fitness, better muscular endurance, lower waist circumference, lower resting heart rate, and lower systolic blood pressure. The association remained significant after adjustment for age, sex, body mass index, smoking status, and sedentary time. Importantly, the relationship was curvilinear. The largest practical gains were observed when participants moved from very low exercise volume toward the 150-299 min/week range, while additional gains beyond approximately 300 min/week were smaller.

The findings are consistent with the general health benefits of physical activity described in previous reviews and public health statements [1]-[4]. However, the present study adds a practical early-adult interpretation by showing how weekly exercise volume relates to a multidimensional fitness profile rather than only to disease outcomes. This distinction matters because young adults may not be motivated solely by distant disease prevention. Observable improvements in aerobic capacity, strength, muscular endurance, and resting cardiovascular markers may be more immediate and meaningful.

The positive association between exercise volume and cardiorespiratory fitness is consistent with evidence that cardiorespiratory fitness is a powerful health marker [5]-[7]. The present results support the idea that even in early adulthood, differences in weekly exercise habits are reflected in measurable aerobic fitness. The magnitude of the association was not extreme, which is appropriate for a free-living sample, but it was large enough to be meaningful at the population level. A difference of several ml/kg/min in predicted VO2max across volume categories can translate into noticeable differences in daily stamina and recreational performance.

The curvilinear pattern observed in Figure 3 and Table 5 is consistent with the broader physical activity and mortality literature, where the largest relative benefits often occur when inactive people become moderately active [8]-[11]. This has important communication value. It allows practitioners to tell low-active young adults that they do not need to become endurance athletes to improve health-related fitness. Reaching the guideline range is a realistic and efficient target. At the same time, higher exercise volumes were not associated with worse fitness in this sample; rather, the additional average benefit became smaller.

The findings also align with exercise prescription principles that emphasize a combination of frequency, intensity, time, and type [12]. Weekly minutes are useful, but they do not tell the whole story. The sensitivity model adjusting for resistance-training days attenuated the exercise-volume coefficient, suggesting that part of the association between volume and composite fitness was explained by higher-volume adults being more likely to perform strengthening activity. This supports public health recommendations that include both aerobic and muscle-strengthening components.

The results are broadly consistent with training studies showing that different amounts and intensities of exercise produce graded changes in fitness, lipids, body composition, and oxygen consumption [13]-[16]. The present study differs in that it observes early adults in real-life settings rather than assigning exercise doses in a controlled trial. This field context introduces greater variability but also strengthens ecological relevance. Most adults do not exercise under perfectly controlled protocols; they combine gym sessions, running, cycling, team sports, recreational activities, and active commuting in varied ways.

Resting cardiovascular indicators showed favorable associations with exercise volume. These findings are compatible with evidence that exercise can lower blood pressure and improve vascular function [17], [18]. The effect sizes for systolic blood pressure were smaller than for fitness or endurance outcomes, which is understandable. Early adults often have normal blood pressure, leaving less room for large reductions. In this context, a modest difference can still be meaningful as part of a preventive pattern, especially when accompanied by a lower resting heart rate and a smaller waist circumference.

The multidimensional approach to fitness is supported by work on field-based health-related fitness assessment [19] and by evidence that fitness in youth and young people predicts later health markers [20]. In the present study, a composite score allowed different components to be interpreted together, while component analyses prevented the composite from hiding important differences. For example, cardiorespiratory fitness and push-up performance showed strong dose-response gradients, while systolic blood pressure was less responsive.

Self-report instruments such as the International Physical Activity Questionnaire are widely used and valuable for surveillance [21]. Still, accelerometry studies show that objective and self-reported activity are not always identical [22]. The present study used a seven-day log supported by wearable summaries when available. This approach is feasible and closer to real program monitoring than laboratory-only measurement, but future studies should integrate device-based intensity and time data more consistently.

The findings also relate to step-based and daily movement research [23]. Structured exercise minutes are only one part of total movement behavior. An early adult may meet exercise guidelines but still accumulate high sedentary time, or may not attend formal exercise sessions but walk extensively during work or commuting. The current analyses adjusted for sedentary time, yet the independent role of movement pattern remains important. Future studies should examine how structured exercise, daily steps, and breaks in sedentary behavior combine to shape fitness in early adulthood.

Body composition findings were consistent with evidence that exercise contributes to weight management and favorable adiposity profiles [24]. The waist circumference gradient was moderate and should not be interpreted as indicating that exercise volume alone determines body composition. Diet, sleep, genetics, and resistance training all matter. Nevertheless, the observed pattern supports the practical value of exercise volume as one contributor to body composition in early adulthood.

Muscular fitness outcomes improved with higher exercise volume, which is consistent with evidence that strength and resistance training contribute to health and function [25], [26]. Because the exposure in this study was total moderate-to-vigorous exercise volume rather than resistance-training volume alone, the results should be interpreted carefully. Higher-volume adults were more likely to include resistance exercise, and the sensitivity analysis showed that this explained part of the association. This supports a balanced prescription: weekly volume should include both aerobic and strengthening activities where possible.

Exercise training responses differ among people due to baseline fitness, genetics, adherence, recovery, and mode of activity [27]. The scatter around the curve in Figure 3 clearly shows this. Some adults with moderate volume had high fitness, while some high-volume adults did not show an exceptional composite score. This variability argues against using weekly minutes as the only judgment of fitness. Instead, exercise volume should be interpreted in conjunction with assessment outcomes, preferences, and recovery capacity.

The biological plausibility of the results is supported by the broad systemic effects of exercise [28]. Regular activity affects cardiovascular, muscular, metabolic, and neural systems. The results, therefore, should not be seen as surprising: greater exposure to exercise is likely to produce a stronger fitness profile. What is practically important is the shape of the curve and the relative size of the differences across achievable categories.

Intensity remains an important unresolved issue [29]. Two adults can report the same weekly minutes but experience different internal loads if one performs vigorous interval training and the other performs moderate steady-state exercise. The present study used moderate-to-vigorous equivalent minutes to improve comparability, but a more detailed intensity distribution would improve future dose-response models. It is possible that some adults could achieve similar fitness gains with lower total time if intensity is higher and recovery is adequate.

Several limitations should be acknowledged. First, the cross-sectional design cannot prove causality. Higher exercise volume may improve fitness, but fitter adults may also choose to exercise more. Second, the sample included early adults from universities, workplaces, and community settings, thereby improving practical relevance but potentially limiting generalizability to clinical populations or elite athletes. Third, exercise mode and intensity were not modeled in sufficient detail to fully separate aerobic, resistance, and mixed-mode effects.

Future research should use longitudinal and intervention designs to test whether increasing exercise volume from one category to another produces the expected improvements in fitness. Studies should also examine how weekly exercise volume interacts with resistance training, sleep, nutrition, mental stress, and sedentary behavior. In early adulthood, these lifestyle factors often change together, and a more complete model would help practitioners move from general advice to individualized exercise guidance.

VI. CONCLUSIONS

This study showed a clear dose-response association between weekly exercise volume and health-related fitness in early adulthood. Adults who accumulated more moderate-to-vigorous exercise each week generally displayed a stronger fitness profile, including higher cardiorespiratory fitness, better muscular endurance, a more favorable waist circumference, a lower resting heart rate, and lower systolic blood pressure. The findings support the value of treating exercise volume as a graded exposure rather than a simple active-or-inactive category. In practical terms, not all adults need the same volume to benefit, but the average pattern indicates that greater weekly exercise is associated with more favorable health-related fitness.

The largest gains were observed when adults moved from very low exercise volume toward the guideline-level range of 150-299 min/week. This is encouraging from a public health perspective because it means that meaningful improvement does not require extreme training. For a young adult currently doing little structured exercise, building toward three to five weekly sessions may produce substantial improvements in fitness and readiness for daily activity. This finding supports positive, realistic communication: the first meaningful step is not to train like an athlete, but to move consistently enough for the body to adapt.

At the same time, the results indicate that higher exercise volumes can be associated with additional benefits, particularly up to approximately 300-450 min/week. Beyond that range, average gains became smaller. This pattern should not be interpreted as a reason to discourage high-volume recreational exercise. Many adults enjoy higher training volumes and may pursue sport, endurance events, or personal performance goals. Rather, the finding suggests that very high volume should be individualized. When the basic public-health target has been achieved, exercise quality, recovery, training mode, progression, and enjoyment become just as important as adding more minutes.

The study also highlights the importance of multidimensional fitness assessment. Weekly exercise volume was associated not only with estimated aerobic capacity but also with muscular endurance, body composition, and resting cardiovascular markers. This supports a broader view of health-related fitness in early adulthood. A useful fitness program should not focus only on one number or one test. Aerobic training, strengthening activity, and sustainable movement habits work together to produce a more complete health profile. For universities, workplaces, and community programs, this means that exercise promotion should combine accessible aerobic opportunities with simple resistance and muscular endurance options.

The similar dose-response pattern in women and men strengthens the relevance of the findings for mixed early-adult populations. Broad weekly-volume targets can be shared across groups, while individual differences should guide exercise type, progression, and support. The findings also reinforce the value of regular monitoring. Exercise logs, simple fitness tests, and resting health markers can help practitioners determine whether an adult is progressing, plateauing, or accumulating volume without corresponding benefit. In summary, successful exercise promotion in early adulthood should prioritize consistency, realistic progression, and a balanced fitness profile. Weekly exercise volume is a practical and meaningful target, and moving low-active adults toward guideline-level activity may provide the greatest and most achievable improvement in health-related fitness.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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