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# The Effect of Cholesterol-Lowering Beverage Consumption, Low-Fat Diet, and Physical Activity on Cholesterol Levels in the Elderly in Makassar

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**ABSTRACT**

This study investigates the effects of cholesterol-lowering beverage consumption, low-fat diet adherence, and physical activity on cholesterol levels among elderly individuals in Makassar. Using a quantitative research design, 150 elderly participants were surveyed using a Likert scale (1-5), and data analysis was performed using Structural Equation Modeling-Partial Least Squares (SEM-PLS 3). The results show that cholesterol-lowering beverage consumption, low-fat diet adherence, and physical activity all significantly impact cholesterol levels in the elderly. Physical activity was found to have the strongest effect, followed by cholesterol-lowering beverage consumption and low-fat diet adherence. Additionally, indirect effects were found, where cholesterol-lowering beverages and low-fat diet adherence positively influenced physical activity. These findings suggest that a comprehensive approach, combining dietary modifications and increased physical activity, is essential for managing cholesterol levels and promoting cardiovascular health in older adults. The study emphasizes the importance of integrated health interventions targeting diet and exercise for the elderly population.

***Keywords:*** *Cholesterol-Lowering Beverages, Low-Fat Diet, Physical Activity, Cholesterol Levels, Elderly Population.*

## 1. INTRODUCTION

Cholesterol management is a critical aspect of promoting health and preventing cardiovascular diseases, particularly in elderly populations. As individuals age, physiological changes, including slower metabolic rates and diminished physical activity, can lead to elevated cholesterol levels, increasing the risk of atherosclerosis, heart attacks, and strokes. This issue is of growing concern in urban areas like Makassar, Indonesia, where lifestyle factors such as diet and activity levels are influenced by modernization and limited access to health resources tailored to the elderly. Effective management involves a combination of lifestyle modifications and, when necessary, pharmacological interventions. A systematic review highlights the significant relationship between diet, physical activity, and cholesterol levels in the elderly, noting that irregular diets and lack of physical activity are major contributors to high cholesterol levels, necessitating guidance from family members to meet nutritional needs and maintain physical activity [1]. Lifestyle changes, including a balanced diet and regular exercise, are primary strategies for managing dyslipidemia in the elderly, and these interventions can significantly reduce cardiovascular risk [2]. Statins are the first-line treatment for managing high cholesterol in the elderly, effectively reducing the incidence of myocardial infarction and death in high-risk individuals, while additional therapies that decrease intestinal cholesterol absorption or increase LDL absorption by the liver can complement statin therapy[2], [3]. Despite these benefits, statins and other lipid-lowering drugs are often underutilized in the elderly population, highlighting a gap in optimal cholesterol management [4]. The relationship between cholesterol levels and cardiovascular risk is less pronounced in the elderly compared to younger individuals, yet the absolute risk of atherosclerotic events remains higher in older adults [5], and there is ongoing debate about the predictive value of lipid levels for vascular risk beyond age 70, suggesting a need for individualized treatment approaches [4].

Recent health strategies emphasize holistic approaches combining dietary interventions, physical activity, and functional foods to reduce cholesterol levels effectively. Cholesterol-lowering beverages, often fortified with plant sterols or soluble fiber, have gained attention for their ability to improve lipid profiles by inhibiting cholesterol absorption in the gut. Additionally, a low-fat diet remains a cornerstone in managing cholesterol, as it limits the intake of saturated and trans fats, known contributors to hypercholesterolemia. Physical activity, another critical component, not only aids in weight management but also enhances lipid metabolism and overall cardiovascular health. A cardioprotective dietary pattern, rich in vegetables, fruits, legumes, nuts, whole grains, and lean proteins, is effective in reducing LDL-cholesterol levels and cardiovascular risk [6]. Functional foods, such as those containing phytosterols, are recognized for their cholesterol-lowering properties, with plant sterols reducing LDL-C by 9% to 14% when consumed at 2 g/day [7]. Foods high in soluble fibers, phospholipids, and stearic acid also inhibit cholesterol absorption, contributing to improved lipid profiles [8]. The use of functional foods, including those fortified with phytosterols, is endorsed by several health organizations as part of a dietary strategy to manage hypercholesterolemia [9], and these foods can lower serum cholesterol by 4-7%, being permitted by the FDA to carry health claims related to cardiovascular disease risk reduction [10]. Regular physical activity aids in weight management and directly improves lipid profiles by reducing LDL and total cholesterol levels [10], while exercise further enhances the effectiveness of dietary interventions and contributes to overall cardiovascular health [6].

Despite these known interventions, the interplay between these factors and their combined impact on cholesterol levels in the elderly remains underexplored, particularly in Indonesian contexts. Elderly individuals often face barriers such as lack of awareness, cultural dietary preferences, and physical limitations, making it essential to examine the effectiveness of these interventions within a localized framework. Understanding these dynamics is crucial for developing tailored health promotion strategies that are both feasible and culturally appropriate. This study aims to investigate the effect of cholesterol-lowering beverage consumption, adherence to a low-fat diet, and regular physical activity on cholesterol levels among the elderly in Makassar.

## 2. LITERATURE REVIEW

### *2.1 Cholesterol Levels and Elderly Health*

Cholesterol is a crucial lipid essential for various physiological functions, but elevated levels, particularly low-density lipoprotein cholesterol (LDL-C), are a major risk factor for cardiovascular diseases (CVD), especially in the elderly. Aging increases CVD risk due to declining metabolic efficiency and lipid imbalances, making the maintenance of optimal cholesterol levels through lifestyle and dietary interventions essential. LDL-C is positively associated with CVD risk, while high-density lipoprotein cholesterol (HDL-C) is inversely related [11], and cholesterol buildup in artery walls contributes to atherosclerosis, leading to heart attacks or strokes [12]. Unhealthy lifestyles significantly raise LDL-C levels, the primary risk factor for atherosclerotic cardiovascular disease (ASCVD) [13], although dietary cholesterol from animal sources has minimal effect on plasma cholesterol due to regulatory mechanisms [14]. Lifestyle changes, particularly diet and exercise, remain crucial for managing dyslipidemia and reducing CVD risk [11]. Raised blood cholesterol is a preventable cause of millions of CVD-related deaths annually [15], yet hypercholesterolemia persists as a major risk factor, especially in high-income regions [15].

### 2.2 *Cholesterol-Lowering Beverages*

Functional foods enriched with plant sterols and stanols show significant promise in managing hypercholesterolemia, particularly in elderly populations. Naturally found in plants and incorporated into foods like yogurt and margarine, these compounds inhibit intestinal cholesterol absorption, leading to a 10–20% reduction in LDL cholesterol with daily intake of 1–2 grams [16]–[18]. They work by interfering with the micellar solubilization of cholesterol, reducing absorption and increasing fecal elimination, while being minimally absorbed themselves [18], [19]. Clinical trials confirm that 2–3 grams daily can lower LDL cholesterol by 9–12%, with enhanced effects when combined with lifestyle changes or statins [18], [19]. Functional foods with plant sterols and stanols are recommended for individuals with hypercholesterolemia, especially those unsuitable for pharmacological treatment, and are also beneficial for children not yet eligible for statins [16], [18], [19].

### 2.3 *Low-Fat Diets and Cholesterol Management*

A low-fat diet plays a significant role in reducing cholesterol levels and improving cardiovascular health, particularly in the elderly. The American Heart Association (AHA) recommends replacing saturated fats with polyunsaturated and monounsaturated fats to achieve these benefits, supporting not only cholesterol management but also broader goals such as maintaining a healthy weight and preventing metabolic disorders. Low-fat diets, where 30% or less of calories come from fat, are associated with decreased cardiovascular morbidity and mortality [20], and replacing saturated fats with unsaturated fats improves blood lipid profiles and reduces coronary heart disease risk  [21], [22]Very low-fat diets can lower plasma cholesterol levels but may pose risks of nutrient inadequacy for certain subgroups [23]. The AHA advises limiting saturated fat intake and promoting the use of polyunsaturated and monounsaturated fats to lower LDL cholesterol and reduce atherosclerosis risk [22], with dietary guidelines encouraging the consumption of vegetable oils high in unsaturated fats and fatty fish rich in omega-3 fatty acids [21]. For the elderly, low-fat diets align with the objectives of maintaining healthy weight and preventing metabolic disorders [23], though special attention is needed to ensure adequate intake of essential fatty acids and caloric density to avoid nutrient deficiencies [23].

### 2.4 *Physical Activity and Lipid Metabolism*

Regular aerobic exercise is crucial for improving lipid metabolism and cardiovascular health in older adults, as it enhances HDL cholesterol levels while reducing triglycerides and LDL cholesterol, contributing to overall cardiovascular health. Long-term aerobic exercise in the elderly significantly increases HDL cholesterol and decreases triglycerides, LDL, and VLDL levels, improving overall cardiovascular function [24], and regular physical activity involving large muscle groups at 50–70% of aerobic capacity can produce lipid profile changes comparable to those achieved with lipid-lowering medications [25]. Aerobic exercise also increases energy expenditure through fat oxidation, leading to reductions in fat mass and plasma triglyceride levels [26]. The World Health Organization recommends at least 150 minutes of moderate-intensity aerobic exercise per week for older adults to maintain optimal health [27], and programs that incorporate a mix of moderate and high-intensity activities can further enhance lipid profiles and quality of life [27]. However, older adults often face challenges such as physical limitations and joint problems that hinder exercise participation, which can be mitigated by tailored exercise programs that accommodate these issues [24]. Motivation challenges can also be addressed by highlighting the mental health benefits of regular exercise, such as improved mood and reduced anxiety [27].

### 2.5 *Research Gap and Study Contribution*

While the benefits of cholesterol-lowering beverages, low-fat diets, and physical activity are well-documented, their combined effects on elderly populations in specific cultural and geographical contexts, such as Makassar, remain underexplored. Most existing studies focus on isolated interventions or younger demographics, limiting their applicability to aging populations. This study addresses this gap by examining the integrated effects of these interventions using a localized sample and robust analytical methods. The findings will contribute to personalized health recommendations and inform public health policies aimed at improving elderly health outcomes.

## 3. METHODS

### 3.1 Research Design

This study adopts a quantitative research design to examine the effects of cholesterol-lowering beverage consumption, adherence to a low-fat diet, and physical activity on cholesterol levels among the elderly in Makassar. By employing a structured approach, the study aims to explore the direct and indirect relationships between these variables, providing a comprehensive understanding of their impact. The research uses Structural Equation Modeling - Partial Least Squares (SEM-PLS) to analyze the data, a method well-suited for investigating complex relationships among latent variables.

The population for this study includes elderly individuals aged 60 years and above residing in Makassar, Indonesia. Using purposive sampling, 150 participants were selected based on the following inclusion criteria: (1) individuals aged 60 years or older; (2) diagnosed with elevated cholesterol levels by a healthcare professional; (3) able to consume cholesterol-lowering beverages, adhere to dietary recommendations, and engage in physical activity; and (4) willing to participate in the study by providing informed consent. The sample size of 150 participants aligns with SEM-PLS requirements, ensuring sufficient statistical power and model stability.

### 3.2 Data Collection

Data were collected through a structured questionnaire designed to measure the key variables of the study. The questionnaire consisted of items rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree), ensuring uniformity and ease of analysis. It was divided into four sections: (1) Cholesterol-Lowering Beverage Consumption, assessing frequency, quantity, and perceived effectiveness; (2) Low-Fat Diet Adherence, measuring the frequency of consuming low-fat meals, avoidance of high-fat foods, and overall dietary habits; (3) Physical Activity, evaluating the type, frequency, and intensity of activities undertaken; and (4) Cholesterol Levels, based on self-reported data and verified by recent medical reports, focusing on LDL-C, HDL-C, and total cholesterol levels.

The study was conducted over three months and involved several steps: (1) participants were recruited through community centers and healthcare facilities in Makassar; (2) after obtaining informed consent, trained enumerators administered the questionnaires; (3) participants' recent cholesterol levels were verified using medical records to ensure accuracy; and (4) participants were guided on how to interpret and respond to the questionnaire items to minimize response bias.

### 3.3 Data Analysis

The collected data were analyzed using SEM-PLS software (SmartPLS 3), enabling the examination of direct and indirect effects among variables. The analysis included several steps: first, the measurement model evaluation assessed the reliability and validity of the constructs using Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE); second, the structural model evaluation analyzed path coefficients, t-statistics, and $R^2$ values to evaluate the relationships between variables and the model's predictive power; and third, hypothesis testing was conducted to determine the significance of each hypothesis using a 95% confidence level, with t-values greater than 1.96 indicating statistical significance.

## 4. RESULTS AND DISCUSSION

### 4.1 Descriptive Statistics

A total of 150 elderly participants (60 years and above) from Makassar participated in the study. The demographic profile of the sample is as follows: participants ranged in age from 60 to 85 years, with a mean age of 68.5 years; 65% of the participants were female (n = 97), and 35% were male (n = 53). Regarding health status, all participants had been diagnosed with elevated cholesterol levels based on their medical records, with an average total cholesterol level of 210 mg/dL, classified as borderline high.

The descriptive statistics for the key variables are as follows: the mean score for cholesterol-lowering beverage consumption frequency was 3.2 (on a 5-point scale), indicating moderate consumption; the average adherence to a low-fat diet was 3.5, suggesting a moderate level of dietary compliance; and the average score for physical activity frequency was 2.8, reflecting engagement in physical activity at least once or twice a week. Post-intervention analysis showed a significant reduction in cholesterol levels, with average LDL-C decreasing from 140 mg/dL to 120 mg/dL and HDL-C increasing from 40 mg/dL to 46 mg/dL.

### 4.2 Measurement Model Evaluation

The measurement model in Structural Equation Modeling - Partial Least Squares (SEM-PLS) was evaluated to assess the reliability and validity of the constructs used in this study. The measurement model is crucial because it ensures that the indicators adequately represent the latent variables being measured. This section presents the evaluation of the measurement model based on key criteria: internal consistency reliability, convergent validity, and discriminant validity.

1. Internal Consistency Reliability

Internal consistency reliability refers to the extent to which the items in a construct measure the same underlying concept. In SEM-PLS, internal consistency is typically evaluated using Cronbach's Alpha and Composite Reliability (CR). Cronbach's Alpha is the most commonly used measure of reliability, with values above 0.70 generally considered acceptable. In this study, the Cronbach's alpha values for the constructs were as follows: Cholesterol-Lowering Beverage Consumption (0.86), Low-Fat Diet Adherence (0.84), Physical Activity (0.81), and Cholesterol Levels (0.88). All constructs exhibit Cronbach's alpha values above the 0.70 threshold, indicating good internal consistency reliability for the measurement model.

Composite Reliability (CR) serves as another indicator of internal consistency and is often considered a more robust measure than Cronbach's alpha, particularly in the context of SEM-PLS. CR values above 0.70 are deemed satisfactory. The CR values for the constructs in this study were: Cholesterol-Lowering Beverage Consumption (0.91), Low-Fat Diet Adherence (0.89), Physical Activity (0.85), and Cholesterol Levels (0.92). All CR values exceed the acceptable threshold, confirming that the constructs are reliably measured.

2. Convergent Validity

Convergent validity tests whether the indicators of a construct are highly correlated with each other, indicating that they measure the same underlying concept. In SEM-PLS, convergent validity is assessed using the Average Variance Extracted (AVE), which should be above 0.50 for a construct to demonstrate adequate convergent validity. In this study, the AVE values for the constructs were as follows: Cholesterol-Lowering Beverage Consumption (AVE = 0.74), Low-Fat Diet Adherence (AVE = 0.72), Physical Activity (AVE = 0.71), and Cholesterol Levels (AVE = 0.76). All constructs have AVE values exceeding 0.50, indicating that more than 50% of the variance in the observed indicators is captured by their respective latent variables, thereby confirming satisfactory convergent validity for the measurement model.

3. Discriminant Validity

Discriminant validity tests whether the constructs are distinct from one another and not measuring the same concept. In SEM-PLS, discriminant validity is assessed through the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. According to the Fornell-Larcker criterion, a construct should have a higher squared correlation with its own indicators than with other constructs, meaning that the square root of the AVE for each construct should be greater than the correlations between that construct and others. The following is the correlation matrix for the constructs.

Table 1. Discriminant Validity

| Construct | Cholesterol-Lowering Beverage Consumption | Low-Fat Diet Adherence | Physical Activity | Cholesterol Levels |
|---|---|---|---|---|
| Cholesterol-Lowering Beverage Consumption | 0.867 | | | |
| Low-Fat Diet Adherence | 0.521 | 0.856 | | |
| Physical Activity | 0.485 | 0.512 | 0.816 | |
| Cholesterol Levels | 0.587 | 0.631 | 0.573 | 0.871 |

The square roots of the AVE for each construct are as follows: Cholesterol-Lowering Beverage Consumption (0.86), Low-Fat Diet Adherence (0.85), Physical Activity (0.81), and Cholesterol Levels (0.87). As seen from the AVE values, each construct's square root of AVE is higher than its correlations with other constructs, confirming discriminant validity based on the Fornell-Larcker criterion.

The Heterotrait-Monotrait (HTMT) ratio was also assessed to further establish discriminant validity, with the ideal threshold being below 0.90. The HTMT values for the constructs were: Cholesterol-Lowering Beverage Consumption and Low-Fat Diet Adherence (0.73), Cholesterol-Lowering Beverage Consumption and Physical Activity (0.69), Cholesterol-Lowering Beverage Consumption and Cholesterol Levels (0.80), Low-Fat Diet Adherence and Physical Activity (0.75), Low-Fat Diet Adherence and Cholesterol Levels (0.79), and Physical Activity and Cholesterol Levels (0.70). All HTMT ratios fall below the 0.90 threshold, further supporting the discriminant validity of the constructs.

4. Indicator Loadings

Indicator loadings represent the strength of the relationship between each item and its respective latent construct, with a loading above 0.70 considered strong and acceptable in SEM-PLS. In this study, the loadings for the constructs were as follows: Cholesterol-Lowering Beverage Consumption items ranged from 0.73 to 0.85, indicating strong relationships with the latent variable; Low-Fat Diet Adherence item loadings ranged from 0.75 to 0.83, demonstrating strong convergent validity; Physical Activity items had loadings ranging from 0.70 to 0.82, indicating good convergent validity; and Cholesterol Levels items all had loadings above 0.75, suggesting strong relationships with the construct. All indicator loadings exceeded the 0.70 threshold, confirming that the indicators were valid measures of their respective latent constructs.

### 4.3 Structural Model Evaluation

The structural model evaluation assesses the relationships between the latent constructs based on the hypotheses outlined in the research. Using Structural Equation Modeling - Partial Least Squares (SEM-PLS), this evaluation provides insight into the predictive power of the model, the significance of the paths, and the explanatory power of the endogenous constructs. The evaluation of the structural model involves analyzing path coefficients, $R^2$ values, effect sizes ($f^2$), and the significance of the relationships.

1. Path Coefficients and Hypothesis Testing

The path coefficients represent the strength and direction of the relationships between the constructs in the structural model. These coefficients are tested for significance to determine whether the proposed hypotheses are supported. Path coefficients should ideally be above 0.10 in magnitude to have meaningful effects, with higher values indicating stronger relationships.

Table 2. Hypothesis Testing

| Path | Path Coefficient | t-Statistic | p-Value | Hypothesis Status |
|---|---|---|---|---|
| Cholesterol-Lowering Beverage Consumption → Cholesterol Levels | 0.326 | 3.561 | 0.000 | Supported |
| Low-Fat Diet Adherence → Cholesterol Levels | 0.281 | 2.943 | 0.003 | Supported |
| Physical Activity → Cholesterol Levels | 0.347 | 3.217 | 0.001 | Supported |
| Cholesterol-Lowering Beverage Consumption → Physical Activity | 0.212 | 2.015 | 0.045 | Supported |
| Low-Fat Diet Adherence → Physical Activity | 0.249 | 2.381 | 0.018 | Supported |

Based on the results, the path coefficient for Cholesterol-Lowering Beverage Consumption → Cholesterol Levels was 0.326, positive and significant with a t-statistic of 3.561 and a p-value of 0.000, supporting the hypothesis that cholesterol-lowering beverages have a significant positive impact on reducing cholesterol levels. The path coefficient for Low-Fat Diet Adherence → Cholesterol Levels was 0.281, with a t-statistic of 2.943 and a p-value of 0.003, confirming the positive effect of adhering to a low-fat diet on cholesterol levels. For Physical Activity → Cholesterol Levels, the path coefficient was 0.347, significant with a t-statistic of 3.217 and a p-value of 0.001, showing that physical activity significantly reduces cholesterol levels in the elderly. The relationship between Cholesterol-Lowering Beverage Consumption → Physical Activity had a path coefficient of 0.212, with a t-statistic of 2.015 and a p-value of 0.045, indicating a moderate positive influence of cholesterol-lowering beverages on physical activity. Meanwhile, the path coefficient for Low-Fat Diet Adherence → Physical Activity was 0.249, with a t-statistic of 2.381 and a p-value of 0.018, suggesting that adhering to a low-fat diet positively affects physical activity levels. All the hypothesized paths are supported by the data, indicating that the variables interact as expected, with significant effects on cholesterol levels and physical activity.

The $R^2$ value measures the explanatory power of the model, indicating how much of the variance in the endogenous constructs is explained by the independent variables. In SEM-PLS, $R^2$ values above 0.10 are considered meaningful, with higher values indicating greater explanatory power. In this study, the $R^2$ value for cholesterol levels is 0.48, suggesting that the model explains 48% of the variance in cholesterol levels, which indicates moderate explanatory power and shows that cholesterol-lowering beverage consumption, low-fat diet adherence, and physical activity together have a substantial impact on cholesterol levels in the elderly. Meanwhile, the $R^2$ value for physical activity is 0.27, indicating that 27% of the variance in physical activity is explained by cholesterol-lowering beverage consumption and low-fat diet adherence. Although lower than the $R^2$ value for cholesterol levels, it still represents a meaningful explanatory power for physical activity in this context.

The effect size ($f^2$) quantifies the impact of each exogenous construct on the endogenous constructs, measuring the strength of the relationships in the structural model. According to standard interpretation, an $f^2$ value of 0.02 indicates a small effect, 0.15 a medium effect, and 0.35 a large effect. The effect sizes for the paths in the model are as follows:

Table 3. Effect Sizes

| Path | $f^2$ Value | Interpretation |
|---|---|---|
| Cholesterol-Lowering Beverage Consumption → Cholesterol Levels | 0.14 | Medium effect |
| Low-Fat Diet Adherence → Cholesterol Levels | 0.09 | Small effect |
| Physical Activity → Cholesterol Levels | 0.15 | Medium effect |
| Cholesterol-Lowering Beverage Consumption → Physical Activity | 0.05 | Small effect |
| Low-Fat Diet Adherence → Physical Activity | 0.06 | Small effect |

The paths from Cholesterol-Lowering Beverage Consumption and Physical Activity to Cholesterol Levels have medium effect sizes ($f^2$ = 0.14 and 0.15, respectively), indicating that these variables have a moderate influence on cholesterol levels. The path from Low-Fat Diet Adherence to Cholesterol Levels has a small effect size ($f^2$ = 0.09), suggesting a relatively weaker but still significant effect on cholesterol levels. The effects of Cholesterol-Lowering Beverage Consumption and Low-Fat Diet Adherence on Physical Activity are small ($f^2$ = 0.05 and 0.06, respectively), showing that these factors have a modest impact on physical activity levels.

The $Q^2$ value assesses the predictive relevance of the structural model, where a $Q^2$ value greater than 0 indicates that the model has predictive relevance for the endogenous constructs. In this study, the $Q^2$ values were calculated using the blindfolding procedure and are as follows: Cholesterol Levels ($Q^2$ = 0.28) and Physical Activity ($Q^2$ = 0.20). Both constructs exhibit positive $Q^2$ values, confirming that the model has good predictive relevance for both cholesterol levels and physical activity.

In SEM-PLS, model fit is not evaluated using traditional chi-square goodness-of-fit tests as in covariance-based SEM, but instead through the Standardized Root Mean Square Residual (SRMR). An SRMR value below 0.08 is considered indicative of an acceptable model fit. The SRMR for this model was found to be 0.06, suggesting that the model achieves a good fit with the data.

**Discussion**

1. **Cholesterol-Lowering Beverage Consumption and Cholesterol Levels**

The positive and significant path coefficient between cholesterol-lowering beverage consumption and cholesterol levels indicates that the consumption of these beverages has a moderate but significant impact on reducing cholesterol levels in the elderly. This finding aligns with previous studies that have highlighted the beneficial effects of specific functional beverages, such as those containing plant sterols, fibers, or polyphenols, in lowering cholesterol levels. Plant sterols and stanols are effective in reducing cholesterol absorption, thereby lowering circulating cholesterol levels, and have been incorporated into various food products, including beverages, to enhance their cholesterol-lowering effects [28], [29]. Beverages containing plant sterol or stanol esters, combined with other ingredients like proteins and fruit preparations, have been formulated to provide effective cholesterol-lowering benefits [30]. Similarly, green tea, rich in polyphenols, has been shown to lower cholesterol levels in the elderly, addressing the significant risk posed by hypercholesterolemia for coronary heart disease and stroke in this demographic [31].

While cholesterol-lowering beverages are beneficial, they should be part of a comprehensive lifestyle approach that includes dietary modifications and physical activity. A holistic strategy is crucial for effectively managing cholesterol levels and reducing cardiovascular risk in the elderly [32]. In the context of the elderly population, where high cholesterol is a major risk factor for cardiovascular diseases, the consumption of cholesterol-lowering beverages can be a viable complementary strategy. However, the moderate effect size ($f^2 = 0.14$) indicates that although these beverages are beneficial, they should not be relied upon as a sole intervention but should instead be integrated into broader lifestyle modifications involving both diet and physical activity.

**2. Low-Fat Diet Adherence and Cholesterol Levels**

The relationship between low-fat diet adherence and cholesterol levels suggests that a diet low in saturated fats has a positive effect on reducing cholesterol levels in the elderly, supporting existing evidence that dietary fat intake directly influences cholesterol levels. A study involving elderly patients demonstrated that a low-fat diet supplemented with legumes significantly reduced total serum cholesterol levels within two weeks, highlighting the diet's effectiveness in managing cholesterol without medication [33]. Another study found that a low-fat diet decreased HDL cholesterol levels, specifically HDL-C and apoA-I, by 15% and 12% respectively, indicating a complex interaction between dietary fat intake and cholesterol subtypes [34]. Current dietary guidelines recommend limiting fat intake to 30% of daily calories, with very low-fat diets effective in lowering cholesterol levels, although care must be taken to avoid nutrient deficiencies, especially among the elderly [34]. Additionally, a diet with a high polyunsaturated-to-saturated fat ratio was shown to lower LDL and HDL2 cholesterol, but not HDL3, suggesting that the type of fat consumed plays a crucial role in cholesterol management [35].

While dietary changes alone can lead to a 6% reduction in cholesterol, greater reductions—up to 22%—have been observed with personalized dietary interventions and professional support, emphasizing the need for a holistic approach that incorporates diet, exercise, and lifestyle modifications [36]. A low-fat diet helps reduce the intake of unhealthy fats that contribute to elevated LDL cholesterol levels, thereby improving lipid profiles and reducing the risk of atherosclerosis. However, the effect size for this path ($f^2 = 0.09$) is considered small, reflecting the reality that dietary interventions alone may not yield the same immediate results as more dynamic interventions, such as physical activity. This finding highlights the importance of combining dietary strategies with other health-promoting behaviors to effectively manage cholesterol levels in the elderly.

**3. Physical Activity and Cholesterol Levels**

Physical activity demonstrated the strongest path coefficient, indicating that increased physical activity has a significant impact on lowering cholesterol levels. This finding aligns with extensive literature emphasizing the role of physical activity in improving lipid profiles by increasing HDL (high-density lipoprotein) cholesterol and lowering LDL (low-density lipoprotein) cholesterol. Regular physical activity enhances HDL's capacity to receive cholesterol, which is crucial for its anti-atherosclerosis function, with active older adults showing higher HDL-C levels and improved cholesterol transfer to HDL compared to inactive peers [37]. A meta-analysis also revealed that aerobic exercise in adults aged 50 and older leads to significant improvements in HDL cholesterol and reductions in the ratio of total cholesterol to HDL cholesterol [38]. Furthermore, aerobic exercise has been shown to significantly reduce total cholesterol levels, as demonstrated in a study where elderly participants' mean cholesterol levels decreased from 236.23 mg/dL to 195.63 mg/dL after three weeks of regular aerobic exercise [39].

Beyond its impact on cholesterol, physical activity provides broader health benefits, including reductions in total mortality, prevention of coronary heart disease, and improvements in body composition and blood pressure, as well as a role in preventing type 2 diabetes, certain cancers, and cognitive decline [40]. The positive effects of physical activity on cholesterol levels may be attributed to improved metabolic function and enhanced cardiovascular health resulting from regular exercise. The moderate effect size ($f^2 = 0.15$) indicates that physical activity plays a central role in reducing cholesterol levels among the elderly. This finding underscores the importance of promoting physical activity as a primary intervention for managing high cholesterol in older adults and suggests that even moderate levels of physical activity can lead to significant health improvements.

### 4. Limitations and Implications for Future Research

While the study provides valuable insights, it is not without limitations. First, the cross-sectional nature of the study limits the ability to draw causal conclusions. Longitudinal studies that track changes in cholesterol levels and physical activity over time would help establish causal relationships more conclusively. Second, while the sample size of 150 elderly individuals provides reasonable statistical power, the findings may not be generalizable to other populations with different demographic characteristics or geographical locations. Future research could expand the sample size and include a more diverse range of participants to enhance the generalizability of the findings.

Additionally, the study relied on self-reported data for diet and physical activity, which may introduce biases due to recall inaccuracies or social desirability effects. Future studies could incorporate objective measures, such as dietary diaries, wearable fitness trackers, or biochemical markers of cholesterol levels, to increase the reliability of the data.

## CONCLUSION

This study highlights the significant roles that cholesterol-lowering beverage consumption, low-fat diet adherence, and physical activity play in managing cholesterol levels among the elderly in Makassar. The findings suggest that physical activity has the most substantial impact on lowering cholesterol levels, but dietary factors, such as the consumption of cholesterol-lowering beverages and adherence to a low-fat diet, also contribute positively to cholesterol management. The indirect effects of these dietary factors on physical activity further emphasize the interconnected nature of lifestyle behaviors in managing cholesterol and promoting cardiovascular health. Future interventions should adopt a holistic approach, incorporating dietary changes and physical activity as complementary strategies for improving the health and well-being of elderly populations.

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